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QUARTERLY PROGRESS REPORT

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Date 1-30-74 Reviewer 137

DIVISION 6 — DIGITAL COMPUTER (U)

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15 JUNE 1957

LINCOLN LABORATORY

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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS ELECTRONIC SYSTEMS DIVISION (AFSC)
HANSCOM AIR FORCE BASE, MASSACHUSETTS 01731

REPLY TO ATTN OF: ALFL (Lincoln Laboratory) 17 Dec 84

SUBJECT: Declassification of Lincoln Laboratory Documents

TO: Mr. M. Wesley/A-109
Security Office
Lincoln Laboratory

1. Reference your letter of 17 Nov 1983 requesting declaassification and public release of MIT Lincoln Laboratory Quarterly Progress Reports issued between June 1952 and December 1958 (see atch 1).

The first major hurdle of this process has been cleared. Attachment 2 authorizes the declassification of the following documents:

"Quarterly Progress Reports - Division 6 - Digital Computer"

15 Jun 1954 (C) (LL # 1, C315172C)
15 Sep 1954 (C) (LL # 1, C315189C)
15 Sep 1956 (C) (LL # 1, C315208C)
15 Mar 1957 (C) (LL # 1, C315206C)
15 Jun 1957 (C) (LL # 1, C315253C) #1715
15 Sep 1957 (C) (LL # 1, C315254C)
15 Dec 1957 (C) (LL # 1, C315255C)
15 Mar 1958 (C) (LL # 1, C315256C)
15 Jun 1958 (C) (LL # 1, C315257C)
15 Sep 1958 (C) (LL # 1, C315258C)
15 Dec 1958 (C) (LL # 1, C315313C)

The next major hurdle is obtaining public release. This will be done through ESD Public Affairs (Mr. John O'Brien).

ORIGINAL SIGNED BY

THOMAS J. ALPERT, Major, USAF
Chief, ESD Lincoln Laboratory Project Ofc

2 Atch
1. Lincoln Laboratory Ltr, 17 Nov 1983
2. NORAD Ltr, 26 Nov 84

Cy to: D. Murphy/B-107 w/atch
W. Hill/L-339 w/atch

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HEADQUARTERS
NORTH AMERICAN AEROSPACE DEFENSE COMMAND
PETERSON AIR FORCE BASE, COLORADO 80914-5001

REPLY TO ATTN OF J30S

16 NOV 1984

SUBJECT Classification Review "Quarterly Progress Reports"

TO ALFL (Lincoln Laboratory)

1. In response to ALFL letter, 28 Nov 83, the (11) confidential documents titled "Quarterly Progress Reports - Division 6 - Digital Computer" and dated 15 Jun 1954 through 15 Dec 1958 have been reviewed. Recommend the documents be declassified in whole since the sage system computer no longer exists and information contained in the documents no longer has an effect on national security.

2. To officially declassify these, documents, the 416L Security Classification Guide OPR, which is at HQ Sacramento Air Logistics Center, McClellan AFB, CA (MMCM), must be contacted with the recommendation to declassify.

JOHN E. MOORS, LCOL, CF
Ch, At Sensors Division

Memo for Record 14 Dec 84

Talked, by phone, with Ed Smalden, Sacramento ALC/MMCM, McClellan AFB, CA. Based on the recommendation in this letter he considers these documents declassified.

THOMAS J. ALPERT, MAJOR, USAF
CHIEF, ESD LINCOLN LABORATORY PROJECT OFC

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QUARTERLY PROGRESS REPORT

DIVISION 6 – DIGITAL COMPUTER (U)

15 JUNE 1957

ISSUED 10 DECEMBER 1957

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY LEXINGTON, MASSACHUSETTS

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DIVISION 6 SUMMARY

Division 6, during March, April, and May 1957, turned the air surveillance portion of the direction center active (DCA) program (Package B) over to Western Electric for initial system testing at the McGuire Direction Center on 20 May ahead of schedule; completed system shakedown tests in the Experimental SAGE Sector (ESS) using Package B; assembly tested Package D and had it ready to be delivered on schedule the first of June; continued active participation in plans for new weapons integration; established a System Office for coordinating proposed changes to the SAGE System; and began installing equipment for the TX-2 experimental computer.

The air surveillance part of the DCA program (Package B, which is about 50% of the entire DCA program) was installed and operating at McGuire, and was turned over to Western Electric for initial system testing on 20 May 1957, three months ahead of schedule. Installation of the DCA program was begun as scheduled on 1 April 1957 at the Stewart Direction Center. The program installation team for the Syracuse Combat Center was being assembled during the quarter.

Analysis of ESS shakedown test results established that all functions covered in Package B of the DCA program conform in all major respects to specifications. Testing with Package D, which adds the functions of weapons direction to the system, will begin on schedule in June.

Group 67 had completed assembly testing of Package D and it was ready to be delivered to Group 64 and 66 at the end of the quarter. A complete redesign of the storage and sequence structure of the DCA program has resulted in a significant increase in useful program operating time within the program frame.

The non-real-time simulation of SAGE functions is progressing. Computer program specifications have been written for the track-while-scan (TWS) part of this simulation which will be used for the initial integration of new weapons into the SAGE System. The modifications to the SAGE System that will be required for initial BOMARC integration have been proposed in a series of memorandums that are consistent with the ADC BOMARC employment plan. ADC accepted, with minor modifications, the proposals presented by Group 61 at the employment meeting for SIF beacon integration with SAGE. Group 61 participated in a review of the ADC employment plan for frequency-division data link and a discussion of the effects that time-division data link will have on the 1959 revised program. The review was a step toward preparing recommendations to be presented at the ADC employment meeting for time-division data link scheduled for 10 June 1957.

Group 68, the System Office, has been organized as a central agency for processing all proposed changes to the SAGE System. All available information pertaining to the proposals and to their possible effect on the system's air defense capability is gathered and coordinated by the System Office. When the costs, delays, and increased capability estimates attributable to the proposed changes have been evaluated by the organizations responsible for design, installation, and operation of the SAGE System, the System Office will prepare a recommendation for concurrence which will lead ultimately to an official Lincoln Laboratory Technical Information Release to the Air Force.

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The TX-2 experimental computer showed the first signs of becoming a physical reality during the quarter. The frame of the TX-2, which will have a 2.5-million bit core memory and which uses transistors extensively, was assembled and installed. Major power supplies were installed and temporarily wired to the frame to provide power for testing registers. Eleven registers, the X-adder, and the X-memory were mounted on the frame and wiring was begun.

R.R. Everett
Division Head

N.H. Taylor
Associate Division Head

S.H. Dodd
Assistant Division Head

J.F. Jacobs
Assistant Division Head

1 November 1957

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TECHNICAL INFORMATION RELEASES

1 March 1957 – 31 May 1957

TIR	Release Date	Material Released
1-196	17 Apr. 1957	Group Report 26-24-75, "Elimination of Jamming Strobes from AN/FST-2," by E.W. Bivans, dated March 1957.
1-197	17 Apr. 1957	IBM Engineering Performance Specification S-154 (PH 57-20029), dated 22 March 1957. (Lincoln Laboratory Memorandum IBM1246.)
1-198	7 May 1957	2M-0705, "Quantizer Settings of an AN/FST-2 operating with an AN/FPS-3," by D.A. Spaeth.
1-199	6 May 1957	6M-4981, "Facilities of the Experimental SAGE Sector," dated 1 April 1957.
1-201	13 May 1957	6M-5121, "Initial Computer Program Available For System Tests at McGuire," by M.H. Cannell (RAND) and S.L. Thompson, dated 8 May 1957.
1-202	22 May 1957	6M-5101, "Changes in the Format of the MORT," dated 26 April 1957.
1-203	29 May 1957	6M-3851-4, "Master Reference List of Equipment Specifications for XD-1," dated 26 April 1957.
1-204	31 May 1957	6M-4971, "Compatibility of AN/FST-2, AN/FSQ-7 Message Formats," by S.B. Ginsberg, dated 1 April 1957.
1-205	31 May 1957	6M-3090-2, "Synchronized Clock System for SAGE System Direction Centers." 6M-3288-3, "Synchronized Clock System for SAGE System Combat Centers."

GLOSSARY

AA	antiaircraft
AAOC	AA Operation Center
a-c	alternating current
AD	Air Defense
ADC	AD Command
ADES	AD Engineering Service
ADPE	auxiliary data-processing equipment
ADSOD	Air Defense Systems Operation Division
ADW	Air Defense Wing
AEW	Airborne Early Warning
AF	Air Force
AFB	AF Base
AFCRC	AF Cambridge Research Center
AFIRO	AF Installation Requirements Office
AFMTC	Air Force Missile Test Center
AGC	automatic gain control
AGET	Advisory Group on Electron Tubes
AI	airborne interceptor
AMC	Air Materiel Command
AMIS	Air Movements Identification Service
APL	Applied Physics Laboratory
AQL	average quality level
ARAACOM	Army Antiaircraft Command
ARDC	Air Research and Development Command
ARTCC	Air Route Traffic Control Center
ASC	Air Situation Coordinator
ASESA	Armed Services Electro-Standards Agency
ASO	Air Surveillance Officer
ASR	automatic send-receive
AST	Air Surveillance Technician
ASTM	American Society for Testing Materials
ATABE	Automatic Target-Battery Evaluation
ATC	Air Training Command
ATCF	ATC Facility
ATO	Air Tactics Officer
ATT	Air Tactics Technician
BISEPS	BOMARC – Interceptor SAGE Experimental Computer Program Simulation
B-N	bariated-nickel
BOSCO	BOMARC – SAGE Compatibility
BTL	Bell Telephone Laboratories
BSO	Battle Simulation Officer
CAA	Civil Aeronautics Administration
CAT	category
CBS	Columbia Broadcasting System
CC	combat center
CCDC	Cape Cod Direction Center
CDC	call direction code
CCS	Cape Cod System
CER	change evaluation request
C&E	communications and electronics
CHT	Charactron tube
CM	core memory
Codan	Carrier-operated antinoise muting system
CP	Command Post
CPO	command pulse output
CRT	cathode ray tube
CS	coding specification(s)
DAB	display assignment bit
DACL	Dynamic Analysis and Control Laboratory
d-c	direct current
DC	direction center
DCA Program	the computer program for the active computer of a SAGE direction center
DCO	Design Control Office
DD	digital display
DDG	DD generator
DDL	Division of Defense Laboratories
DDR	digital data receiver
DDT	digital data transmitter
DGP	Data Generation Program
DRIP	Data Reduction for Interception Program
EADF	Eastern Air Defense Force
ECM	electronic counter measure
ECP	engineering change procedure
EG&G	Edgerton, Germeshausen & Grier
EMAR	experimental memory address register
EPSCOM	Equipment Program Services Committee
ESS	Experimental SAGE Sector
ERA	Electronic Research Associates
FF	flip-flop
FGD	fine-grain data
FM	frequency modulation
FORX	FGD orientation with Raydist and calibrated Mark X
G/A	ground-to-air
GFI	gap-filler input
GSR	group selection register
HEC	Hazeltine Electronics Corp.
IBM	International Business Machines Corp.
ID	identification
IFF	identification – friend or foe
INS	interceptor simulator
IPS	initial program specification
IRE	Institute of Radio Engineers
JETEC	Joint Electron Tube Engineering Council

GLOSSARY (Continued)

KSR	keyboard send-receive
LPO	Lincoln Project Office
LRI	long-range radar input
LTPS	Lincoln tube process specification
MAR	memory address register
MC	marginal checking
MCD	marginal checking and distribution
MDI	manual data input
MEL	minimum equipment list
M-G	motor-generator
MIL	Military
MISP	Manned Interceptor Simulation Program
MITE	multiple input terminal equipment
MOC	Mission Operations Center
MPPS	Master Program Preparation Section
MTC	Memory Test Computer
NAS	Naval Air Station
NET&T	New England Telephone and Telegraph Co.
n-p-n	negative-positive-negative
NRL	Naval Research Laboratory
OB	output buffer
OMR	operational modification(s) request
OPS	operations
OT	Overlap Technician
PCC	Planning Coordination Center
PCD	power control distribution
PCO	Production Coordination Office
PIUMP	Plug-in unit mounting panel
p-n-p	positive-negative-positive
PPI	planned position indicator
PRF	pulse repetition frequency
pps	pulses per second
PT	Plotting Technician
QPR	Quarterly Progress Report
RADC	Rome Air Development Corp.
RAFD	Rome Air Force Depot
RAND	Research and Development Corp.
RC	register containing
R-C	resistance-capacitance
RD	radar data
RECI	Request for Engineering Change and/or Information
RETMA	Radio, Electronics, Television Manufacturers Association
r-f	radio frequency
ROTR	receive-only typing reperforator
S&EC	Scientific and Engineering Computation
SAC	Strategic Air Command
SAGE	Semiautomatic Ground Environment
SAHL	semiautomatic height-finder live
SAR	storage address register
SBT	surface-barrier transistor
SC	Signal Corps
SCEL	SC Engineering Laboratory
SDG	Simulated Data Generation
SDV	slowed down video
SIF	selective identification feature
SIZ	security identification zone
SNORT	SAGE Non-Real-Time Simulation Study
SO	Systems Office
SOE	Systems Operation Exercise
SOP	standing operating procedure
SOT	Systems Operations Test
SPIS	SAGE Program Identification Service
SSTP	SAGE System Training Program
STEP	Simulated-Tracking Evaluation Program
STINCO	SAGE-Talos Integration Committee
STP	System Training Program
STRANGE	SAGE Tracking and Guidance Evaluation System
SWIG	SAGE Weapon Integration Group
TAPE	Technical Advisory Panel for Electronics
TBS	training and battle simulation
TCAP	Tactical Channel Assignment Panel
TD	track data
TIR	Technical Information Release
TRACALS	Traffic Approach Control and Landing Service
TT	Texas Tower
TWS	track-while-scan
UHF	ultra high frequency
VCM	vibrating coil magnetometer
VHF	very high frequency
WAD	Weapons Assignment Display
WADC	Wright Air Development Center
WE	Western Electric Co.
WGT	weapons guidance and tracking
WISE	Whirlwind I SAGE Evaluation
WL	warning light
wpm	words per minute
WSEG	Weapons System Evaluation Group
WSPO	Weapons System Project Office
WWI	Whirlwind I
XT	Crosstell, Crosstalk

SYSTEM DESIGN

GROUP 61

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I. SYSTEM DESIGN
GROUP 61

A. SUMMARY

Group 61 continued the study of problems associated with the integration of new weapons systems into the SAGE System: Currently under study are manned interceptors, the BOMARC missile system, time-division data link, the employment of the IFF Mark X Selective Identification Feature (SIF) System, and the non-real-time simulation of SAGE functions required to support weapons integration tasks.

A group consisting of representatives of Lincoln, IBM, the 4620th ADW, and manufacturers of manned interceptors, under the chairmanship of ARDC, has been organized to assist in manned-interceptor integration efforts. The first meeting was held early in May, when a series of orientation lectures was conducted at Lexington.

Procedures and plans for a series of weapons integration tests using the Cape Cod System have been discussed, with prospects that a first series of tests using the F-102A can begin in August.

The modifications to the SAGE System required for initial BOMARC integration have been proposed in a series of seven memorandums covering initial tactical capability, operational changes, missile tracking, guidance and general program changes, AN/FSQ-7 equipment changes, and changes to SIF and data-link equipment.

Preliminary specifications have been issued covering the computer programs for the BOMARC/SAGE Compatibility (BOSCO) flight test program. The BOSCO computer programs will be used in live tests at Patrick AFB as well as in simulated tests at Kingston, N. Y., where the XD-2 computer is located. Plans for simulation studies were presented at the BOMARC/SAGE flight test status meeting in May which outlined the requirements of the initial phase of testing. The BOSCO computer programs will proceed as scheduled with a target date of 1 November 1957 for completion.

Group 61 has participated, with representatives from Groups 311, 61, 67, and the 4620th ADW, in a review of the ADC employment plan for frequency-division data link and the impact that time-division data link will have on the 1959 revised SAGE program. Recommendations based on this review and on discussions planned with ADC and Boeing will be presented at the ADC employment meeting for time-division data link scheduled for 10 June 1957.

Computer program specifications have been written for the track-while-scan (TWS) portion of the non-real-time simulation of SAGE functions. The major features of the simulation effort (including the aforementioned program specifications, estimates of manpower requirements, and proposals for writing mathematical specifications and computer programs) will be presented at a Boeing/IBM/Lincoln meeting scheduled for 18 to 20 June 1957 at Seattle.

The proposals presented by Group 61 at the ADC employment meeting for SIF, held late in April, were accepted with minor modifications and the ADC employment plan for SIF in SAGE will be issued. Changes to the computer programs, related to the interceptor tracking to be incorporated in the 1959 revised program, are covered in the employment plan as well as modifications to the AN/FST-2 equipment.

D. R. Israel

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B. MANNED INTERCEPTORS

1. Integration Studies

A broad proposal for the manned interceptor capability of the 1959 revised SAGE program is scheduled to be completed by 1 August 1957. This plan will be prepared by Group 61 in conjunction with the SAGE Weapons Integration Group (SWIG). In preparation for this effort, one member of Group 61 has been assigned to the study of each of the following interceptors: F-89H, F-89J, F-101B, F-102A, F-104A, and F-106A. The problem areas anticipated with the use of these manned interceptors in the SAGE System – data link, SIF, cruise control, modified close control, snap-up, zoom-up, foldback, raid tactics, special weapons, handover, crosstelling, base scramble procedures, return-to-base, weapons assignment, and re-attack – were discussed in a series of daily meetings held during April. Informal notes based on each of these discussions have been prepared.

The SAGE Weapons Integration Group (SWIG), proposed by the Air Force at a meeting at Wright Field in January* was organized in May under the chairmanship of Col. R. S. Carter of ARDC. Representatives of this committee include:

Mr. M. Brookman of North American Aviation, Inc. (F-86D, L)
Mr. C. Dresser of McDonnell Aircraft Corp. (F-101B)
Mr. R. Dickinson of Lockheed Aircraft Corp. (F-104A)
Mr. H. Hickey of IBM
Mr. L. Jeffery of Group 61, Lincoln Laboratory
Col. J. D. Lee of the 4620th ADW
Mr. H. Mazurkeiwicz of Convair (F-102A, F-106A)
Mr. H. Palmer of Hughes Aircraft Company (MG-10, 12, 13, 14 fire control systems)
Mr. R. Paxman of Northrup Aircraft, Inc. (F-89H, J)

A series of orientation lectures was begun early in May with a discussion of some of the fundamentals of aerodynamics by Mr. Dickinson. Other lectures were delivered by Lincoln people on computers, air defense functions, and communications. At the conclusion of the lecture series, members of the group returned for one week to their respective organizations to start the supporting studies of the integration problems associated with their interceptors.

2. Testing in the Cape Cod System

Divisions 2 and 6 have established procedures for conducting tests in the Cape Cod System (CCS) necessary to the weapons integration effort. Procedures for testing in ESS will be established later. Group 61 will write up a broad plan covering the required flight tests over the next year, working directly with weapons contractors and others concerned with requirements for such tests. Detailed test specifications for all tests, or series of tests, will also be written by Group 61 with the help of others concerned. Group 22 will determine the requirements on computer time, test facilities, computer programming, data reduction, etc., and will coordinate with Group 23 as necessary. Group 61 or the weapons contractor will supply additional manpower or specific instrumentation when required. Group 22 will submit the data resulting from these tests to Group 61 which will, with the help of the weapons contractor, perform any further data analysis required and prepare the test reports of the results.

*Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 March 1957) Sec. I.B.2.

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The first proposal for weapons integration tests in CCS was submitted by Convair and involved a series of tests of the direction of F-102A's on various final-turn attacks. Groups 61 and 22 suggested modifications to the proposal, and, according to present plan, initial testing of F-102A's in CCS will involve two test series: (A) co-altitude, final-turn, and beam attacks with the interceptor remaining at a constant speed, 0.86M, and (B) with a post-turn acceleration to V_{max}. Detailed test specifications for both series are being prepared by Group 61 and it is believed that Series A testing can begin in August.

L. R. Jeffery

C. BOMARC

The changes required in the SAGE System for initial BOMARC integration have been proposed in the series of memorandums listed below. The change recommendations are consistent with the ADC BOMARC employment plan prepared in February of this year.

Proposed Changes to the SAGE System for Initial BOMARC Tactical Integration

Memo No.	Title, Authors, and Date
6M-4890	"Proposed Initial SAGE/BOMARC Tactical Capability," by D. R. Israel and H. E. Anderson, 13 February 1957
6M-4891	"Operational Changes to the SAGE System for Initial BOMARC Tactical Integration," by D. W. Ladd, S. Litsios, and S. Benson (RAND), 4 April 1957
6M-4892	"Missile Tracking in the SAGE System for Initial BOMARC Tactical Integration," by E. W. Wolf and S. H. Goldberg, 4 April 1957 (To be issued by Boeing Airplane Co. as D5-1536)
6M-4893	"Guidance Program Changes to the SAGE System for Initial BOMARC Tactical Integration," by R. W. Shur (IBM) and A. Talkington (RAND), 24 April 1957 (To be issued by Boeing Airplane Co. as D5-1537)
6M-4894	"General Program Changes to the SAGE System for Initial BOMARC Tactical Integration," by S. J. Hauser, J. W. Shay, 1 April 1957 (To be issued by Boeing Airplane Co. as D5-1538)
6M-4895	"AN/FSQ-7 Equipment Changes for Initial BOMARC Tactical Integration," by L. V. Ruffino (IBM), 23 April 1957 (To be issued by Boeing Airplane Co. as D5-1539)
6M-4896	"Proposed Changes to SIF and Data-Link Equipment for Initial BOMARC/SAGE Tactical Integration," by H. E. Anderson, J. May, and E. Wolf, 15 February 1957 (To be issued by Boeing Airplane Co. as D5-1540)

A supplement to 6M-4890, issued on 18 April 1957, describes the method of tracking BOMARC for the period prior to the time that the SIF beacon becomes operational. It is assumed that, in the absence of SIF returns, the missile will respond to the ground beacon interrogator with a single basic Mark X pulse. The methods of tracking without SIF codes will differ somewhat from those outlined in 6M-4892, particularly in the following areas:

(a) The correlation of basic Mark X returns with the BOMARC track is less reliable than with SIF returns. Thus, the smoothing used with Mark X data will be heavier than that used with SIF returns.

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(b) The personal-identity feature of the SIF codes is not available with the basic Mark X returns and, therefore, the position of Mark X and track data will be the only basis for correlation.

(c) The climb characteristics of a BOMARC must be stored in the computer to obtain an accurate missile position for reliable track initiation.

(d) The firing rate in the Mark X tracking scheme will be lower than when SIF returns are used.

1. BOMARC Testing

a. BOSCO

IBM has issued preliminary computer program specifications for the BOMARC/SAGE Compatibility (BOSCO) flight test program. Lincoln recommended that tracking procedures be modified to be more like SAGE. This recommendation was accepted. The initiation-scoring scheme will be changed somewhat and provision for two modes of operation will be made. One mode will be used for tracking missiles with Mark X only; the other if SIF is available for the tests.

Changes are now being proposed to the BOSCO program to make it a more useful tool in studies of BOMARC/SAGE tactical integration since, if operated in real-time with simulated inputs, BOSCO can become a satisfactory facility for early evaluation of some important features of the BOMARC employment plan. It is expected that an extension of contract coverage will be necessary for IBM to participate in such a BOSCO simulation effort.

Under present plans, both live and simulated tests would use the BOSCO programs. Two versions of them will be written, one for live tests at Patrick Air Force Base and one for simulation studies. Test plans for the simulation studies were presented at the BOMARC/SAGE flight test status meeting on 27 May. These plans outline, for the initial phase of testing, the purpose and scope of the test, the number of tests in the initial phase, operational procedures, computer time requirements for data-generation and data-reduction, examples of test configurations, and plans for the analysis of the reduced data. Detailed plans for initial tests will be drafted early in June. The geography of the New York Sector will be programmed where appropriate and it has been agreed that the missile simulator will generate data only to lock-on, to sense for lock-on, and to make a coarse evaluation of target interceptability. The simulation program will proceed as scheduled with a target date of 1 November 1957 for completion.

b. Montgomery Sector

The Montgomery Sector (formerly the Gunter Subsector) was discussed at an Air Force meeting held on 9 and 10 April at Wright Air Development Center. Lincoln presented a plan for demonstrating multiple BOMARC firings which was accepted by the meeting. The schedule calls for the demonstration to be completed before September 1959. The air defense operational date for Montgomery will be delayed somewhat, depending upon subsystem tests to be performed by Western Electric. RAND will supply the revised computer program to the New York Sector in a form which will fit into the small memory at Montgomery. The details of this plan have been published in 6M-4994, "Gunter Employment Plan," 15 April 1957.

H. E. Anderson

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D. DATA LINK INTEGRATION

The ADC employment plan for frequency-division data link and the impact time-division data link will have on SAGE have been reviewed by representatives from Groups 311, 61, 67, and the 4620th ADW.

An employment meeting for time-division data link will be held at RCA, Camden, New Jersey, on 10 June 1957, where Lincoln will make recommendations regarding message content and format for manned interceptors and BOMARC's that will operate with the time-division data link. Because both time-division and frequency-division data links will be in simultaneous operation for an indefinite period, the SAGE computer program must contain the time-division facilities as well as frequency-division facilities.

Typical of the basic aspects of integration are the following BOMARC/time-division data link problems:

(a) The frequency of the data-link receiver in the missile will have to be changed as the missile passes from one sector to another in order to accomplish handover.

(b) Mode 2 (emergency) operation creates a phone line netting problem, since neither the ground transmitters nor the missiles can quickly be changed to a new frequency. The use of more than one frequency in time division seems to be a solution.

(c) Addresses must be designated for each sector in order to accomplish allocation of missiles at a squadron shared by two direction centers. The launch command, initial-guidance command, and change-frequency command, will have to come from one direction center which will be considered a relay station if the launching has been requested from another sector.

H. E. Anderson
L. R. Jeffery

E. SIF

Lincoln Laboratory presented proposals* for the employment of SIF in SAGE at the ADC employment meeting held the last week of April in Rome, New York. The proposals were accepted with minor modifications for the ADC employment plan which will be published shortly. This plan will call for computer program changes related to interceptor tracking to be incorporated into the 1959 program revision, and for equipment modifications to the AN/FST-2.

The tracking of in-flight manned interceptors on Mode 2 personal-identity beacon replies will be similar to that of the BOMARC tracking specified in 6M-4892. As in the present system, the program for manned interceptors will be able to command track at the discretion of the Intercept Director. Automatic initiation of manned interceptors may be possible if some convenient method can be found to inform the computer of corresponding track and SIF numbers either by adding switches to the WD or WDT consoles, or by installing automatic status-reporting equipment. It would also be desirable to give the Intercept Director the benefit of the increased knowledge gained from the personal-identity code. One solution may be to use extra channels on the display system to display the aircraft track number with an uncorrelated beacon return when the two SIF numbers agree. This solution, however, presents many difficulties which would have to be solved.

*"Proposed Mark XI Employment Concept for SAGE," M.I.T. Lincoln Laboratory Report 6M-5088 (22 April 1957).

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1. AN/FST-2

The first meeting of the SIF-AN/FST-2 committee was held 14 to 16 May 1957. The committee was composed of Messrs. D. Sullivan of Burroughs, A. Paradis of Boeing, K. Perry of Group 24, and S. Goldberg of Group 61. This meeting was the first step toward specifying the SIF detector attachment for the AN/FST-2 needed to permit it to receive IFF Mark X (SIF) beacon returns. The new SIF detector will be designed to operate in option A, B, or C of the employment plan with minor adjustments. If possible, switch action will suffice; if not, the equipment will be modified by changing logic cards.

2. Tracking Error

Tests performed late in the quarter, using the SAGE Tracking Evaluation Program (STEP) to simulate radar data from one site, and reducing the scan time from 12 to 6 seconds to simulate overlap coverage from two sites, indicated a significant improvement in tracking capability using overlap coverage over that using single coverage. These tests were run with tracks making 90° maneuvers as was previously done with single coverage. A few tests were run with the following parameters:

β – radar blip-scan ratio	1.0, 0.9, 0.8, 0.7
λ – radar clutter density	0.002, 0.004, 0.008 pieces per frame per circular mil.
v – aircraft speed	1.0 Mach, 0.5 Mach
a – aircraft horizontal acceleration	0, 0.5, 1.0

Although all combinations of the above parameters were not run, enough tests were made to indicate that the tracking error decreased approximately by one half over that of single coverage. Even more significant, the number of aircraft around the turn was 100 per cent except when β equalled 0.8 and a equalled 1 g. A better evaluation of the tracking capability of overlap coverage can be made when the SNORT simulation (see Section F) becomes operational.

S. Goldberg
E. Wolf

F. SIMULATION STUDIES

Plans and preparations are progressing for the large-scale simulation of the automatic SAGE tracking and guidance functions. This SAGE Non-Real-Time (SNORT) simulation will have a capacity for 150 tracks, 75 simultaneous interceptions, and will use the existing simulated data generation program (SDG) for ESS, which includes provisions for overlap radar coverage. The tracking functions will be programmed first, followed by the BOMARC interceptor functions. Manned-interceptor simulations will be added subsequently.

Preliminary estimates for the tracking and BOMARC functions indicate a series of computer programs totaling some 25,000 instructions and at least 200 man-months of work. The major features of this effort will be presented at a meeting of Boeing, IBM, and Lincoln personnel to be held in Seattle 18 to 20 June. At this meeting, it will be proposed that Boeing write the mathematical specifications for missile assignment, guidance, and path simulation and also supply

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personnel to write the associated computer programs under Lincoln supervision. Boeing will also help to prepare test plans and establish analysis requirements. Data recording and analysis programs will be written by IBM. Still unresolved is the problem of who will write the target-tracking, missile-tracking, and Mark X data-generation programs.

Program specifications for the track-while-scan (TWS) portion of SNORT are being written, as well as a description of the BOMARC weapons guidance and tracking (WGT) portion. The total TWS portion, including tables, is expected to require from 12,000 to 13,000 registers of IBM 704 core and drum storage, of which 6500 to 7000 will be used for instructions. Among the projected uses of the TWS facility are (1) study of the effects of (a) overlap radar coverage on tracking and (b) radar location and orientation errors; (2) determination of tracking effectiveness (a) under crossing track situations and (b) for maneuvering tracks.

A. R. Shoolman
E. W. Wolf

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ESS INSTALLATION

GROUP 62

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II. ESS INSTALLATION
GROUP 62

A. SUMMARY

Group 62 has directed a large part of its activity this quarter toward eliminating the equipment difficulties encountered during ESS shakedown testing and reported by Group 64. It was found that, for the most part, the actual equipment problems were minor in nature and it is expected that as ESS operators gain experience, efficiency in the operation of the equipment will improve.

Of the equipment problems investigated, the following are significant:

(1) Initial ESS shakedown tests using overlap radar data from the Bath and South Truro heavy radars gave higher registration errors than specified. An investigation of radar orientation and an analysis of the computer program were started during the quarter.

(2) All telephone headsets in the ESS direction center will be replaced with a type that is expected to be more comfortable and easier to use.

(3) Fifteen additional line finders have been installed in the Bldg. F telephone exchange to avoid the communication bottleneck foreseen as more and more of the system is put into use.

(4) Instances of faulty data entering the system have been attributed to logical inadequacies in the design of the long-range radar input channels. IBM modified two such XD-1 channels and will write a proposal and submit it to Lincoln covering changes to be made to XD-1.

Only three subsystems tests were run during the quarter. All three were height-finder error-rate tests and used the Bath, South Truro, and Montauk systems. Bath turned in good data for analysis in all three tests, South Truro responded in only one of the three, and the difficulties previously reported for Montauk continue.

J. A. O'Brien
W. J. Canty
R. S. Fallows

B. ESS EQUIPMENT

April and May were devoted to investigating the equipment problems reported by Group 64 as a result of ESS shakedown testing. Methods of improving radar orientation for more accurate registration of overlap tracking data are being studied; the studies include both the equipment and the computer programs. With the cooperation of IBM, improvements have been or will be effected in the ESS direction center equipment or operation. Light-gun reliability has been improved by specifying a more uniform gain setting; light-gun operation has improved since IBM distributed instructions to ESS operators. Difficulties with LRI input channels were solved and modification of the channels was under way by the end of the quarter.

1. Radar Orientation

ESS tracking performance with overlap data from the Bath and South Truro heavy radars showed, during ESS shakedown tests, average measured registration errors of less than 1/2 mile between the two sites. These errors, however, are still higher than specified. Overlap tracking

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accuracy is greatly influenced by orientation of the radars, coordinate transformation methods, and tracking program design.

Five flight tests were run in May, during which an airplane flew several times through the beam of a searchlight at South Truro between 9:00 and 11:00 p.m. (Operation Moonbeam). Since the real position of the aircraft was known to be directly over the South Truro site, the test provided a means of closely examining the registration of the radar returns from Bath and South Truro. The results of these tests are being analyzed in order to calculate the theoretical error in radar registration that is produced by the data-processing programs, and to measure the actual differences between AN/FST-2 reports and correlated track data for comparison with the predicted differences.

Near the end of the quarter, the possibility of a discrepancy became apparent in the coordinate transformation part of the DCA program as used in ESS and small errors had been detected in the orientation of the heavy radars. Groups 62, 64, and 21 are analyzing these and other possible sources of error.

2. Telephone Headsets

ESS operators have complained since the earliest shakedown tests that the telephone headsets are unsatisfactory; the earpieces are uncomfortable, the headband is too small, the distance from earpiece to mouthpiece is too short, and some operators need a push-to-talk feature. Mr. D.J. Deary of the New England Telephone and Telegraph Co. recommended replacement of all headsets and a request was therefore forwarded to D.R. MacBeth of Group 21.

3. Telephone Line Selectors

Fifteen additional PBX line finders were installed in the Bldg. F telephone exchange by the end of the quarter. At the start of ESS shakedown tests last December, it became apparent that a severe communication bottleneck would result as more and more of the system was put into use, since the original system design did not assume that observers would use telephones, nor that a tactical conference line would be installed in the TBS room.

4. Pushbutton Failure

The failure of pushbuttons to latch properly has resulted in instances of ineffective, or only partially effective, switch actions during ESS testing. IBM studied the problem and installed a switch module of a new design for comparison and analysis. Over a period of two weeks' operation, IBM maintenance people found no fault with the replacement module and ESS operators seemed satisfied with it. Information regarding the improved switch action of the trial module was forwarded to the IBM Product Engineering Group at the end of the quarter.

5. LRI Monitor

A timing mechanism was installed on the LRI (long-range radar input) monitor camera to provide, at the option of the operator, a completely automatic exposure over a range of from 8 to 320 seconds with a variable interval of from 2 to 15 seconds between frames. This installation does not prevent manual operation should it be desired, but use of it releases one operator for more efficient service elsewhere.

6. Display Adjustment

ESS operators have reported that their efficiency is lowered and their actions impaired due to variations in adjustments of focus, intensity, and image positioning in situation display consoles. In an effort to establish some measure for intensity, which is difficult to judge by eye, IBM discussed adjustment procedures and demonstrated a meter that could be used in console maintenance for establishing settings. At the end of the quarter, IBM recommended that the operator control for intensity be reinstalled for analysis on five consoles.

7. Light Guns

a. Intermittent Failure

Track initiation during early ESS shakedown tests was slow and uncertain because light guns at times apparently failed to fire or the action was not received by the computer. A second action with the same gun and the same switch settings would usually produce the desired results. In May, IBM advised that three production light guns would be obtained for comparison with those in XD-1. However, very few specific complaints were reported after testing with Package B was begun and difficulties that were reported were accompanied by alarms and seemed to be due to operator error. By the end of the quarter, no additional information had been received which would indicate equipment failure.

b. Sensitivity Criteria

The gain setting of light guns was not originally specified. As a result, the gain varied from gun to gun and operators accustomed to sensitive (high gain) guns were unable to operate with less sensitive guns. The gain on some guns was set so low that they would operate only when they were perpendicular to and in direct contact with the scope face. Others would operate inches away and over a wide angle. After study, IBM established gain adjustments on the basis of the rise time (0.5 v within 15 μsec) that the phototube in each light gun must meet. IBM also forwarded copies of instruction for light gun operation for distribution to all ESS operators who use them. By the end of April, the basic problem seemed to be solved and as operators become more experienced, light gun efficiency is expected to improve.

c. Red Light Intensity

Early in February it was concluded that the intensity of the red light used to center light guns on a target was too great, thus obscuring the radar data and resulting in slow activation. IBM has solved the problem by including an intensity adjustment which is checked in their regular monthly preventive maintenance program.

8. LRI Channels

Faulty data entering the system during ESS shakedown tests has been attributed to logical inadequacies in the design of the LRI channels, which do not detect faults in messages before they reach the LRI drum. IBM modified two XD-1 input channels, using Burroughs equipment, as follows:

(a) Fast-shift pulses were withheld while the buffer register remained full. Thus, the possibility was eliminated of transferring a part of a message remaining in the buffer register onto the drum even though the parity of the message might be incorrect. Before the channels were modified, fast-shift pulses were generated whenever the primary register filled up, though the buffer register might not be emptied of previous messages. (The previous message would not be destroyed, but would be shifted until it shifted out a data bit.)

(b) Sync pulses were withheld during fast-shift time, since they can destroy the contents of the primary register while the contents are in the process of fast-shifting into the buffer register. The remainder of the message in the buffer register could be transferred onto the drum with an incorrect parity.

(c) Data pulses were withheld during the interval of two timing pulses on either side of the sync pulse, since spurious data pulses that occur within two timing pulses on either side of the sync pulse are counted into the over-all parity of the message, but are not transferred onto the drum. Therefore, if both a spurious data pulse and an error in the message should occur within the interval, the input parity count would be correct, but after the message is transferred onto the drum, one of the data pulses would be left behind and the word on the drum would have an incorrect parity.

Early in April, the input alarm difficulties were considered solved since, during two weeks of ESS operation, only one incorrect word had passed through the modified input channels. LRI

TABLE I

PERCENTAGE OF ACCURACY OF REPLIES
HEIGHT-FINDER ERROR-RATE TESTS, ESS SUBSYSTEMS
(March 1957)

Comparisons Made	Bath				S. Truro	Montauk	Goal	Remarks
	Radar A			Radar B				
	3/7	3/14	3/28	3/28	3/7	3/28		
Height exact	100	93	100	97	92	0	99	Input parity alarms on the AN/FST-2 at Montauk prevented receipt of any useful data from that site. (See Quarterly Progress Report, Division 6, 15 March 1957).
Range								
−2 ± 1 n.mi.	72	52	44	70	77	–	90	
−2 ± 2 n.mi.	93	92	76	99	100	–		
Azimuth								
0° ± 1°	85	80	73	77	93	–	90	
0° ± 2°	100	97	94	99	93	–		
Task Assignment exact	100	–	100	100	99.2	–	–	
Flight Information correct	100	–	100	97	0*	–	–	

NOTE:
* 100% correct, except that the least significant bit in "Number of Aircraft" was wrong in every reply.

problems, as they affect AN/FSQ-7 and XD-1 equipment, were discussed with IBM at Kingston on 1 May 1957 and a proposal covering permanent changes to be made to XD-1 will be written by them and submitted to Lincoln for concurrence.

9. Mapping Fluid and Applicator

Data being read through the masking on GFI mapper consoles and area discriminators was attributed to the mapping fluid and applicator. All masking fluid was removed from the Mapper Room and replaced with a new type that has been prepared under more rigid requirements. New wicks for the containers and Flowmaster pens were obtained and in use during ESS shakedown tests by the first of May and by the end of May, after a month's trouble-free use, were considered satisfactory.

10. Height-Finder Subsystems

Three error-rate tests were run using the Bath, South Truro, and Montauk height-finder radars, as shown in Table I. On 14 March, the height-finder function of the DCA program was again checked,* using targets of opportunity and the two Bath height-finder radars, with the

TABLE II
HEIGHT-FINDER INTEGRATION TEST – DCA PROGRAM
(14 March 1957)

	Radar A	Radar B
Height Total number of requests:	60	57
Plausible live aircraft height replies	20%	10%
"Zero" height replies	7%	30%
"No Replies"	0%	4%
Correct "No Action" replies	73%	56%
Range Total number of comparisons:	17	26
-2 ± 1 n.mi.	41%	88%
-2 ± 2 n.mi.	59%	96%

TABLE III
RADAR FLIGHT-TEST COMPUTER PROGRAM TEST
(28 March 1957)

	Bath		
	Radar A	Radar B	S. Truro
Exact height comparisons	94%	88%	38%
"No Replies"	2%	3%	23%
"Zero Replies"	1%	1%	10%
Wrong replies	1%	7%	3%
Bisected returns on aircraft	2%	1%	26%

* Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 March 1957), Sec. II, B.1.b.

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results shown in Table II. The Radar Flight-Test Computer Program (the single-track tracking program) was tested on 21 and 28 March. Results of the 28 March test summarized in Table III reflect the fact that South Truro equipment is in the process of installation and test. Program Errors found during these tests were discussed with Bell Telephone Laboratories who are writing the computer program and they are making the necessary corrections.

I. Aronson, J. H. Bunting, C. J. Carter, F. E. Irish, J. A. Malouin, T. J. Sandy, A. Werlin

C. CIRCUIT SUPPORT

1. Data Service for McGuire

The problem of recording Bell data service transmissions at McGuire is being investigated by Group 62. Bell data service transmissions consist of three separate signals, each on a pair of wires – one pair containing a data, one a sync, and one a timing signal. The straight-forward way of recording would be to use three channels, one for each signal. But this method would be extremely wasteful of tape recorder channel space when one considers that the same signal in the Lincoln data service can be recorded on a single Ampex channel. A study of the problem is under way.

2. Order Counter for XD-1

A unit has been built to count the number of times an instruction is used in XD-1 during a cycle of the DCA program. An order-counter system using a Berkeley Model 7360 counter was obtained which counts and displays up to 10 million at a maximum frequency of 2 Mcps. The counter was tested at the operation frame, using the centralized probe system, by running a program with a known number of orders. Pulse and level amplifiers and gating circuits have been built for the counter for use with the XD-1 probe system, and the unit is now ready for use on the computer.

3. Probe System for XD-1

The centralized probe system was completely installed and ready for test by the end of April using a currently available Tektronix 545 oscilloscope. Representatives from Tektronix visited Lincoln on 26 March to demonstrate their pre-production model of the 551 dual-beam scope. They informed us that they also have in development a number 555 dual-beam, double-sweep scope. Since the 551 will be adequate for our uses only if a delaying sweep feature is added, the 555 is being considered.

4. Fire Detection

By the end of the quarter, two types of detection systems were tested that had been submitted by leading manufacturers of fire detection and protection equipment. Simulated fires were started by overloading a two-watt resistor at the bottom of a module and, after flame was apparent to the eye, the alarm indicated fire within 3 to 5 seconds, which is considered good time for our purposes. Further tests are planned to determine the nature and type of fire, the amount of CO_2 needed, and time of "soak" required. The modules are under positive pressure from the air conditioning system, which further complicates the planned tests.

R. J. Callahan, B. W. Barrett, S. T. Coffin, F. R. Durgin, M. J. Flanagan, A. Hingston, L. Hodes, R. C. Jahn, R. B. Paddock, G. F. Sandy, Jr.

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ADVANCE DEVELOPMENT

GROUP 63

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III. ADVANCE DEVELOPMENT
GROUP 63

A. SUMMARY

Assembly of the equipment and circuitry for the TX-2 computer was started and, by the end of the quarter, the frame had been assembled and modified to include facilities for power, pulse, and in-out wiring. The major power supplies were delivered, installed, and temporarily wired to the frame to provide power for testing registers. Eleven registers, the X-adder, and the X-memory were mounted on the frame, back-panel wiring of them was partly completed, and inter-register wiring was begun. The new power-supply control system has been completed, installed, and is operating satisfactorily. Many of the transistor plug-in units have been received and are being tested.

A system is being developed whereby the situation display seen in a direction center will be transmitted over a telephone line and duplicated at an external site, such as an air base or radar station. The console frame has been built and is operating satisfactorily with a Charactron. Exhaustive testing will begin when the new storage Tonotypotron is delivered.

Investigations of vacuum-evaporated, magnetic films as possible memory elements has continued. The switching pulse of thin films was seen and photographed on an E. G. & G. travelling-wave-tube oscilloscope and the switching time was measured and found to be approximately 4.0 millimicroseconds. Variations in chemistry over film spots is a serious problem.

A direct-input communication system of utility programs has been written for TX-0. It contains over a dozen routines and assists the programmer in debugging and modifying his program at the console.

W. N. Papian
C. L. Corderman
J. B. Goodenough

B. MAGNETIC MATERIALS

The Magnetic Materials Section is conducting the following three major studies: Fundamental investigations, evaporated magnetic films, and ceramics. The fundamental investigations establish the relationship between the engineering parameters used in designing practical electronic components and the preparation procedures of the ceramist or metallurgist who must supply the best magnetic materials for a given component. Evaporated magnetic films are being studied in an effort to develop a faster, lower-power storage element for digital computers than those now in use. Ferrite memory cores of varying grain sizes, thermistors, microwave ferrites, and ferrites for microwave filter elements, are being studied in the ceramics laboratory, where the memory-core production facility is also maintained.

1. Fundamental Investigations of Magnetic Materials

The mechanisms responsible for the magnetic and electrical properties of materials are analyzed as well as the dynamic characteristics of these properties under the influence of dynamic perturbing forces. This analysis relates the engineering parameters to specimen dimensions or physical characteristics and also to more fundamental material parameters which

can be measured on pure, single-crystal specimens. The investigation also involves a study of the relationship between chemistry and these fundamental material parameters. Finally, the techniques are developed for making materials of a given chemistry with the desired physical characteristics.

a. Crystallography and Preparation

A number of compositions belonging to several metal-oxide systems were synthesized and studied during the quarter with respect to magnetic and crystallographic properties. These efforts are part of a program designed to investigate the magnetic interactions between the various transition-metal cations which can occupy the interstices of an oxygen-anion crystal lattice. The substances studied this quarter may be conveniently classified according to crystal structure.

(1) Rock-Salt Systems

MnO-NiO, MnO-CoO, PdO-NiO:– It is possible to prepare complete ranges of solid solutions between MnO and NiO, MnO and CoO. The three individual oxides, MnO, NiO, and CoO crystallize with the rock-salt structure and possess similar lattice parameters. If it were possible to induce the formation of super structures, i.e., to order the two pairs of cations, an exchange interaction between Ni^{++} and Mn^{++}, or between Mn^{++} and Co^{++}, would possibly give rise to a net spontaneous magnetization. Two solid solutions, $Mn_{0.5}Ni_{0.5}O$ and $Mn_{0.5}Co_{0.5}O$, were prepared and annealed for several weeks at 800°C. However, magnetization measurements have yielded nothing of interest.

A solid solution of PdO in NiO could not be synthesized. Coprecipitation of the two oxides followed by ignition at 700°C, yielded two distinct phases.

$Li_x^{+}Ni_{1-2x}^{++}Ni_x^{+++}O$:– The study of this system has included the measurement of saturation magnetization values at the temperature of liquid helium, the Curie points, and crystal lattice parameters. The ferrimagnetism of compositions in which x varies from 0.33 to 0.50 appears to be a consequence of the ordering of Li^{+} and Ni^{+++} cations. The anti-parallel alignment of atomic moments on Ni^{++} and Ni^{+++} cations that occupy alternate (111) layers of octahedral interstices in a rhombohedrally distorted, cubic-close-packed oxygen lattice results in a net observable magnetic moment. The rhombohedral distortion of the original cubic, rock-salt lattice increases slightly with increasing concentration of Ni^{+++} ions. The Curie points lie between the temperature of liquid nitrogen and 0°C.

(2) Spinel Systems

$M_{1-x}^{++++}Mn_x^{++}\left[Mn_{2-x}^{++}M_x^{++++}\right]O_4$:– Several attempts have been made to synthesize a substance with this formula in order to look for a magnetic interaction between Mn^{++} cores that occupy the two kinds of lattice sites in the spinel crystal structure. Unfortunately, the only system presently amenable to study offers a very limited, single-phase region of composition ($x \cong 1.0$), where the observed magnetic moment must be small. A greater degree of success is offered for a similar study of Co^{++}. The substance, $Ge_{0.2}^{++++}Co_{0.8}^{++}\left[Co_{1.2}^{++}V_{0.8}^{++++}\right]O_4$, has been prepared and identified as a cubic spinel.

(3) Perovskites

The preparation and structure of $LaRhO_3$ and $LaCoO_3$ has been completed. Rhodium oxide reacts with lanthanum oxide at 1100°C to form a lanthanum rhodium oxide, with a perovskite-like structure. Calculations based on X-ray data show that $LaRhO_3$ belongs to the space group $D_{2h}(16)$-Pb_{nm} with four formula weights per unit cell. The lattice constants are a = 5.524 Å, b = 5.679 Å, c = 7.900 Å. Determination of the number of "molecules" per unit cell, and chemical analysis, indicate that the formula is $LaRhO_3$.

Lanthanum oxide reacts with cobalt carbonate to form lanthanum cobalt oxide with a perovskite-like structure. $LaCoO_3$ belongs to the space group, $D_{3d}(5)$-R3m, with two formula weights per unit cell. The dimensions of the rhombohedral pseudocell are a = 7.64 Å, α = 90°42'. The dimensions of the primitive rhombohedral cell are a_p = 5.436 Å, α_p = 60°48'. The multiply primitive hexagonal cell, in terms of which the rhombohedral cell may be described, has the following dimensions: a = 5.424 Å, c = 13.068 Å.

Compounds of two new systems $LaNi_xCr_{1-x}O_3$ and $LaNi_xMn_{1-x}O_3$ have been prepared and a comparison of structure and magnetic properties will be made with the series $LaNi_xFe_{1-x}O_3$. Compounds of the series (R · E) $Cr_xFe_{1-x}O_3$, where (R · E) = La, Nd, Sm, have been prepared, and the effects of the lanthanide contraction on the structure of the rare-earth, mixed-transition, metal oxides are to be studied.

b. Magnetic Measurements

A program has been undertaken to measure the fundamental parameters of various magnetic materials over a wide range of temperatures. This program requires a complete investigation of all parameters on any one single-crystal sample if the problem of obtaining a satisfactory dynamical equation for magnetic materials is to be achieved.

(1) Theory and Measurements

A theory previously developed by this laboratory* of the flux-reversal process in polycrystalline ferrites relates the significant engineering parameters for memory cores and switch cores to more fundamental material parameters. It also assumes the validity of the Landau-Lifshitz dynamical equation of motion:

$$\frac{\overrightarrow{dM}}{dt} = \gamma(\vec{M} \times \vec{H}) - \Lambda(\vec{M} \times \vec{M} \times \vec{H}) \quad .$$

Recently Prof. H. B. Callen† has proposed a new equation of motion:

$$\frac{\overrightarrow{dM}}{dt} = \gamma(\vec{M} \times \vec{H}) - \Lambda_o |\vec{M} - \vec{M}_o| \{\vec{M} \times (\vec{M} \times \vec{H})\}_1$$

where γ is the gyromagnetic ratio, M_o is the equilibrium value of the magnetization M in the applied field H, and the subscript 1 denotes a unit vector. From a comparison of these equations, the new and the old relaxation frequencies, Λ_o and Λ, are related by

*N. Menyuk and J. B. Goodenough, "Theory of Flux Reversal in Polycrystalline Ferromagnetics," J. Appl. Phys. 26, 8-18 (1955).

†H. B. Callen, "Modified Ferromagnetic Dynamical Equation," Bull. Am. Phys. Soc., Series II, 2, 128 (1957).

$$\Lambda_o = \frac{\Lambda}{M^2} \frac{|\vec{M} \times (\vec{M} \times \vec{H})|}{|\vec{M} - \vec{M}_o|} \quad .$$

Since this relationship is field-dependent, Callen's formulation can be expected to tend toward a field dependence of the velocity of a domain wall which differs from the linear dependence derived from the Landau-Lifshitz equations.

We have begun an experimental program designed to unambiguously distinguish between the two suggested equations of motion as they apply to domain-wall velocity. This will be done by measuring A, K, and M_s on ferrite single crystals using the vibrating-coil magnetometer; Λ will be measured by microwave resonance experiments, followed by a direct measurement of the wall velocity on a window frame as a function of applied field. Since all these quantities vary with temperature, the measurements are to be carried out over a temperature range of from 1.5°K to 225°C.

The difficulty in obtaining stoichiometric ferrite single crystals is overcome by making all measurements on a single disc, and a window frame cut from that disc. Thus, our results will be internally self consistent.

(2) Experimental Results

Measurements have been begun on two samples, which are tentatively labelled sample #2 and sample #3. Since an exact determination of the composition of these samples will involve damaging the sample, the analysis must await completion of our measurements. Therefore, our experimental results to date are expressed in a normalized form.

Magnetization M_s:– The saturation magnetization curves, normalized to saturation at 0°K, are shown in Fig. 63-1 for samples #2 and #3. Although the Curie temperature of sample #2 is well above 210°C, the measurement was cut off at this point to avoid any possibility of damaging the crystal. The magnetization curve of sample #3 was carried to its Curie temperature of 223.5°C. Within the limits of accuracy of the thermocouple calibration, the Curie point can easily be determined to within ± 0.25°C using a low-field measurement.

Anisotropy Constants K_1 and K_2:– The anisotropy energy density in cubic crystals has the form

$$fex = K_1(\alpha_1^2\alpha_2^2 + \alpha_2^2\alpha_3^2 + \alpha_3^2\alpha_1^2) + K_2(\alpha_1^2\alpha_2^2\alpha_3^2)$$

plus higher order terms which are usually unnecessary to consider in practice. The terms, α_1, α_2, and α_3, represent the direction cosines between the direction of magnetization and the principal cubic axes. In domain-wall calculations, the second-order anisotropy term is ignored because of the difficulty of including it in the calculation. The calculation remains reasonably valid since the mean value of $\alpha_1^2\alpha_2^2\alpha_3^2$ is only 1/21 that of $(\alpha_1^2\alpha_2^2 + \alpha_2^2\alpha_3^2 + \alpha_3^2\alpha_1^2)$.

The values of the anisotropy constants of samples #2 and #3, normalized to unity at 0°K, are shown in Figs. 63-2 and 63-3. Sample #2 apparently undergoes a transition between 4.2°K (liquid-helium temperature) and 77°K (liquid-nitrogen temperature). Work of a qualitative nature indicates this transition is abrupt and probably lies between 4.2°K and 20°K. The nature of the transition will be investigated more thoroughly upon the arrival of a thermometer usable

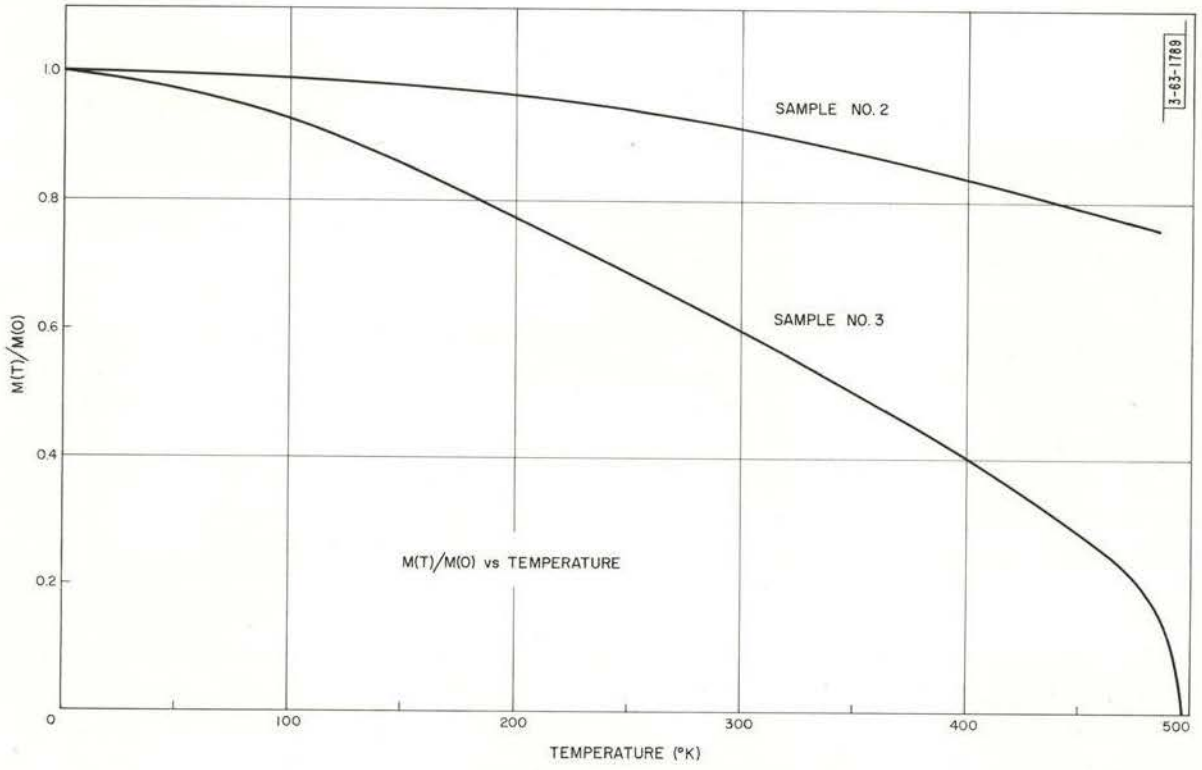

Fig. 63-1. Saturation magnetization of samples of ferrite single crystals.

in this temperature range. Sample #3 does not exhibit any observable discontinuities. However, the low temperature change in K_1 is proportional to $\left[\frac{M(T)}{M(O)}\right]^{17}$, which is far greater than the theoretical value of $\left[\frac{M(T)}{M(O)}\right]^{10}$ given by Van Vleck and others.*

The values of K_1 and K_2 are determined by measuring the areas between curves of M_s vs H measured in the [111], [110], and [100] directions. K_1 can be determined to accuracies of approximately 2 per cent. The determination of K_2, however, involves the subtraction of large numbers to obtain a relatively small difference, so the accuracy of the resultant data is poor. This can be seen in Figs. 63-2 and 63-3.

Exchange Constant A:— The exchange constant, A, is best determined from the change of magnetization with temperature in the vicinity of absolute zero. According to spin-wave theory, the magnetization near absolute zero follows the relationship

$$M(T) = M(O) \cdot (1 - CT^{3/2})$$

and the exchange constant, A, can be related directly to the constant C.

With regard to this measurement, it should be pointed out that the collective electron model of ferromagnetism predicts a relationship of the form $M(T) = M(O) \cdot (1 - CT^2)$. Since this derivation is less rigorous than that of the spin-wave theory, the $T^{3/2}$ law is generally assumed to

*J. H. Van Vleck, "The Theory of Ferromagnetic Anisotropy," Proc. Conf. on Mag. and Mag. Mat., 6-15 (1957); F. Keffer, "Temperature Dependence of Ferromagnetic Anisotropy in Cubic Crystals," Phys. Rev. 100, 1697-98 (1955).

GROUP 63

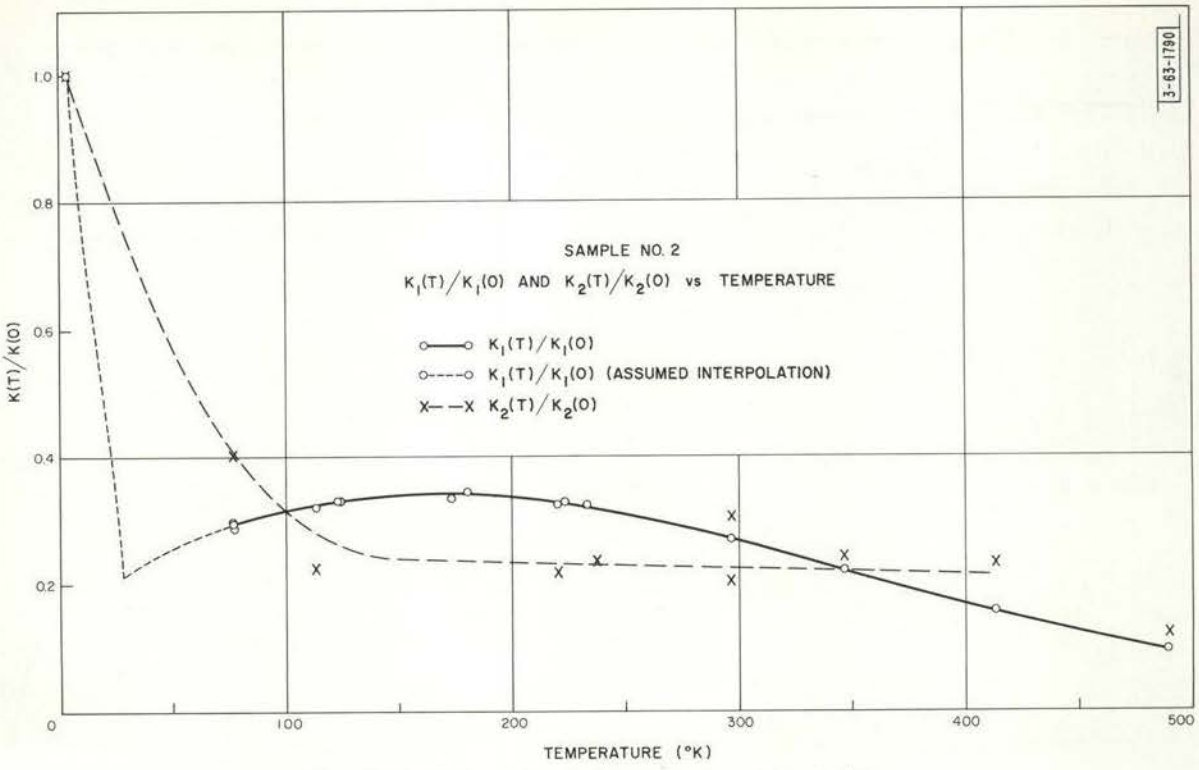

Fig. 63-2. Values of anisotropy constant, Sample #2.

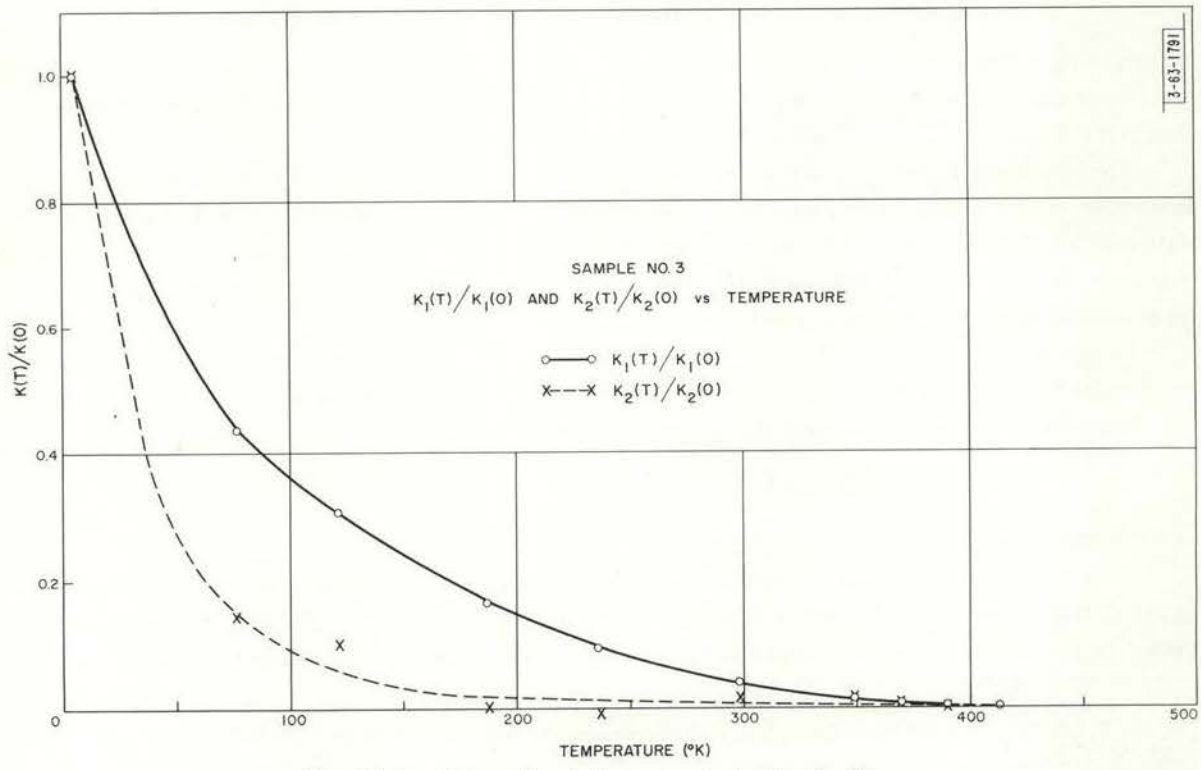

Fig. 63-3. Values of anisotropy constant, Sample #3.

be correct. However, because of the small magnetization variation in the low temperature region, there has been no experiment which conclusively demonstrated the validity of the $T^{3/2}$ law over the T^2 law. Since such information is of considerable fundamental significance in the field of ferromagnetism, we intend to conduct this experiment on antiferro-, ferro-, and ferrimagnetic materials. The inherent sensitivity of the vibrating-coil magnetometer should permit us to differentiate successfully between the two predictions in the temperature region below liquid nitrogen.

(3) The Vibrating-Coil Magnetometer

As reported in the previous quarterly progress report, the electronic circuitry from the vibrating coil to the output has been completed. It includes a new input circuit capable of independently varying the phase and amplitude of the signals from each of the vibrating coils, a sharply peaked 34-cycle pass filter, and a phase-sensitive detector. The detector output is sent directly to a recorder.

In addition, a number of auxiliary units to be used in conjunction with the magnetometer have been designed during this quarter, some of which have also been built.

(a) The vacuum system for pumping directly over liquid helium has been completed. With this new system, temperatures of 1.3°K have been attained, and anisotropy measurements have been taken at this temperature.

(b) It has been found that pumping over liquid helium in the metal helium dewar causes contraction of the dewar as a function of temperature. In order to overcome this effect, a new system employing the glass helium dewar has been designed. It is believed that the new system will permit direct measurement of the magnetic moment versus temperature of a sample below 4.2°K.

(c) A device for semiautomatically varying the magnetic field over any range desired is now in operation. It has been used successfully during the course of anisotropy measurements.

(d) Design modifications have been made in the carbon-resistor unit in order to ease the problem of manufacture. The unit is expected to be completed within a few weeks and will be used for temperature measurements in the range immediately above liquid helium.

(e) The 8" diameter pole pieces were replaced with some of 12" diameter and an improvement of two orders of magnitude has resulted in the double-coil system.

2. Evaporated Magnetic Films

The primary purpose of investigating evaporated magnetic films is the development of a storage element for digital computers that will switch faster and require less power than those now in use. The study is divided into the following three phases:

First, the feasibility of the basic physical concepts must be proved. Considerable effort has been put into instrumenting measuring equipment which will drive and give undistorted output wave forms in the 1 to 10 mμsec range, and it is expected that clean measurements will be made during the next quarter. Measurements to date indicate that magnetic films have all of the potential which was anticipated.

The second phase of the problem is the control of the coercivity of the high-speed flux-reversal process and the elimination of the low-speed process, both of which processes exist in magnetic films. The high-speed process is a

simultaneous rotation of the elementary magnetic moments. The low-speed process involves a sequential rotation of the atomic moments through the creation of expanding domains of reverse magnetization which are separated from the regions of original magnetization by transition regions called domain walls. The high-speed coercivity is directly proportional to the magnetic anisotropy within the film. Therefore, both the magnetic anisotropy and the nature of the magnetic domain walls which can be present in the films have been investigated during this quarter.

The final phase is the development of controlled evaporation procedures which permit uniformity of films over an array in any one evaporation and reproducibility from array to array. Chemical analyses during this quarter have shown that present evaporation techniques give a wide variation in chemistry, and therefore in magnetic properties, from film to film within any one array. Since the entire array is deposited in one evaporation, the origin of these chemical variations is not obvious yet. Studies will continue.

a. Switching and Resonance

Instrumentation:— The principal experimental problem in studying pulse switching and ferromagnetic resonance in thin films in the frequency range of 10 to 5000 Mcps is the development of a suitable rf bridge. Present designs allow the observation of clean switching pulses down to 20 mμsec; sine-wave balance can be achieved all the way out to about 1000 Mcps. Switching studies are possible in the 1 to 10 mμsec range, using the E. G. & G. scope, but the wave forms are not yet very clean. However, new techniques which are working so well in the sine-wave case have not yet been applied to the switching case and it is hoped that when they are, clean switching in the 1 to 10 mμsec range will be possible.

Another use of the rf bridge is in measuring the anisotropic nature of the magnetic energy due to the structure of the film, i.e., the $E(\Theta)$ which enters into the switching theory. By rotating the film in the bridge, a curve much like a traditional torque curve is obtained. In some films, as many as eight easy directions appear to be present.

Theory:— The switching theory of magnetic films has been discussed in previous quarterly progress reports. The observation of low-frequency (500 to 2000 Mcps) ferromagnetic resonance in these films was first reported by members of Group 35 who used a cavity technique. Subsequently this resonance has been observed using the rf bridge mentioned above. The observation is particularly useful to the fundamental theory of magnetic relaxation and will be actively studied in the next quarter. As a tool for investigating the structure and quality of films, this resonance technique should prove exceptionally valuable. Preliminary results seem to support the theoretical and experimental switching studies that have been reported previously.

b. Domain-Wall Theory

The small coercive forces of films of Fe, Ni, Co, and $FeNi_3$, 1000 Å thick, are of the order of 300, 150, 50, and 5 oersteds, respectively. Present wall models lead to a wall energy proportional to $K_{xtal} + 2\pi M$, where $2\pi M$ represents an effective demagnetizing anisotropy. Since K_{xtal} for the above materials is in the same sequence of decreasing order as the coercive forces, it seems natural to look for a model which will reduce the contribution to the wall energy that results from demagnetization and increase the contribution from K_{xtal}. Such a model has been devised, and the mathematical details are being worked out.

c. Production of Films

In order to improve the ultimate vacuum of the evaporator and to attain lower pressures during evaporation, several changes in the system were proposed:

(1) The replacement of rotary seals employing rubber O-rings with a bellows valve.

(2) The replacement of the deposition-field coils inside the bell jar with a new set of external coils.

(3) The installation of a liquid nitrogen trap near the substrate holder in the bell jar.

The new coils have been wound and installed and a power supply has been built that can reduce uniaxial or rotating a-c fields of up to 25 oe. The liquid-nitrogen trap has also been installed and has improved the vacuum by almost one order of magnitude (3×10^{-7} mm ultimate vacuum, 2×10^{-5} during deposition). In addition, a protection circuit has been added to the system to shut off and cool the diffusion pump in case of power failure or pressure rise in the bell jar above a preset value. A water-pressure safety control has been received and will also be installed.

d. Measurements

Slow Switching:– Loop-tester measurements on the films produced in the evaporator show that for films evaporated in an a-c or d-c uniaxial field, a uniaxial anisotropy is observed. Evaporation in a rotating a-c field lowers the uniaxial anisotropy, but does not make the film isotropic. A fourfold anisotropy is seen in these films that suggests crystallographic ordering. Loop testing shows that there can be as many as eight easy directions in some films. Some films which exhibited fourfold symmetry were examined on the loop tester in a system that permitted switching at 90° instead of the usual 180° reversal. The output wave forms for 90° and 180° switching were identical.

Fast Switching:– A new transmission line was built and a new pickup loop was designed and built. The new loop is supported on a stretched membrane which can be positioned in the line to balance magnetic pickup; and permits films to be changed without disturbing the balance. The switching pulse of a thin film was seen and photographed on an E. G. & G. travelling-wave-tube oscilloscope and the switching time was measured and found to be approximately 4.0 mμsec for a normalized longitudinal field near 1 oe and a transverse field of about 1/2 oe.

e. Chemical Studies of Thin Permalloy Films and Melts

A statistical sampling of an 80-20 Permalloy melt showed that Fe and Ni segregated throughout the melt. Segregation of phases was apparent on the etched surface of a melt.

An experiment was designed to determine whether or not compositional differences occurred within a slide of a thin Permalloy film; a difference of 3 per cent in Fe/Ni composition was found. When 1/2" spots were evaporated, a random variation in composition of 7 per cent Fe/Ni was found.

GROUP 63

3. Ceramics

a. Studies of Grain Size in Memory Cores

Regular memory core material was fired with small additions of calcium oxide, which acts as a flux and causes the growth of larger grains. The size of grains was studied in respect to the amount of CaO added and the sintering temperature employed. A composition containing 2 per cent added CaO, sintered at 1300°C for ten hours, yielded the largest grain size (118 μ). The same composition fired at 1280°C for five hours and then at 1324°C for another five hours yielded a grain size of about 49 μ and a squareness ratio of 0.99. The average grain size of regular memory-core material is about 12 μ.

b. Thermistors

Thermistors are electrical conductors with high negative temperature coefficient of resistance over a specified range of temperatures. Preliminary to a systematic chemical study of suitable materials for these devices, there has been an investigation of suitable metal-ceramic electrical contacts and preparation procedures to yield pieces of uniform density. (The attainment of high and uniform density is also important for microwave ferrites.)

Specifications have been received for a thermistor which will control the initial current through the filament of a thermionic vacuum tube. An element is required that will offer an electrical resistance of 100 ohms at 25°C and 0.1 ohm at 200°C. The most promising material that has been studied is a cobalt-substituted, nickel-manganite ($NiMn_2O_4$). It is believed that the negative temperature coefficient of resistivity in $Ni^{++}Mn_2^{+++}O_4$ is the consequence of a phase transition from cubic to tetragonal symmetry. By substituting various cations for the Ni^{++} and Mn^{+++}, the temperature of this transition can be increased or decreased and the electrical characteristics can be varied accordingly. A systematic study has been started.

c. Microwave Ferrites

The possible microwave ferrites under investigation have been magnesium-manganese ferrites, which show promise at L-band, and yttrium-iron garnets. Variations in chemistry will be tried after satisfactorily high densities have been obtained in these materials. Several compositions in the $MgO\text{-}MnO\text{-}Fe_2O_3$ system and the compound yttrium ferrite, $Y_3Fe_2(FeO_4)_3$, offer potential microwave applications. Processes are being investigated (e.g., high-temperature firing followed by annealing and by hydrostatic pressing) in an attempt to produce ceramic pieces with approximately the theoretical density.

d. Filter Ferrites

The fourth objective of the ceramics laboratory is the development of a satisfactory ferrite for microwave filter elements. This component requires a material with a high magneto-mechanical coupling coefficient. Initial investigations are in the system nickel ferrite with small additions of cobalt ferrite.

A high magneto-mechanical coupling coefficient depends upon a large magnetostriction and a high permeability. Since maximum values for these two properties are not obtained simultaneously, a compromise is sought which will give the best practical material. The magnetostriction

of nickel ferrite can be increased by small additions of cobalt ferrite. The pertinent properties of cobalt-substituted nickel ferrite are being studied as a function of the amount of cobalt ferrite added and the sintering temperature. Nickel ferrite with 2 per cent cobalt ferrite, fired at 1350°, has given the highest value for the coupling coefficient so far. Higher and more useful values for the coupling coefficient appear possible with a further slight increase in the percentage of cobalt ferrite.

C. TRANSISTORS

1. Life Tests

Transistors from all operating systems have been retested during the past quarter as listed in Table I.

TABLE I

Operating Circuit	No. and Type of Transistor	Operating Hours
Life test flip-flop	32 SBT*	15,000‡
Direct-coupled shift register	16 SBT	12,000‡
TM-1 multiplier	99 SBT	15,000
TX-0 register drivers (inverters)	120 SBT	2,200
Shielded shift register	97 SBT	12,000‡
EMAR	160 SBT	1,600
TX-0 register drivers (emitter-followers)	42 MAT†	1,300
Diode-coupled shift register	16 SBT	11,000‡
TM-1 type shift register	125 SBT	6,545‡
Shelf life tests	14 SBT	17,000
RC coupled shift register	16 SBT	12,000‡
Unshielded shift register	99 SBT	11,000‡
Total number of transistors	804 SBT 42 MAT	

*Philco L-5122 †Philco L-5134

‡These units have shelf life of 6,000 hours in addition to operating time.

Initial and present parameter measurements have been made and distributions plotted of the parameter values and of the changes in parameter values. When present estimates being made of power dissipation in some of the circuits are completed, the data will be summarized.

No concise breakdown of the information is available as yet, but changes appear to be of the order of magnitude and direction that would be expected. Nothing has appeared which would tend to shake our confidence in the surface-barrier transistor as a reliable device under conditions of large-scale digital computer operation.

GROUP 63

2. Transistor Switching Theory

Johnston has extended the methods developed in Part I of "Transient Response of Junction Transistors"* to the drift or graded-base transistor. The partial differential equation for hole density in the base of a one-dimensional transistor is solved by LaPlace transforms. A transfer function is then obtained for common-base, common-emitter, and saturation operation. The common-base expression is

$$I_c(s) = I_e(s) \frac{\gamma_N e^{w/f}}{\cosh \sqrt{\frac{w^2}{D_p} s + \frac{w^2}{f^2}} + \frac{w/f}{\sqrt{\frac{w^2}{D_p} s + \frac{w^2}{f^2}}} \sinh \sqrt{\frac{w^2}{D_p} s + \frac{w^2}{f^2}}}$$

where w/f is a measure of the built-in field.

The collector current resulting from a step of emitter current is found by conventional inversion methods for various values of w/f. The improvement in switching time due to the built-in field is found to be less in the common-emitter configuration than in the common-base. For the assumed one-dimensional model, storage times are lengthened by the built-in field but the model is shown to break down in the saturation region.

D.J. Eckl
Patricia Fergus
R.C. Johnston
C.T. Kirk, Jr.

D. MEMORY

1. 256^2 Memory

A number of small modifications have been made on the 256 × 256 × 38 memory that have resulted in increased margins and allowed the cycle time to be reduced to 6.0 μsec.

An intensive investigation conducted in May on all circuits of the memory to determine the causes of some basic circuit problems accomplished the following:

(a) The prf sensitivity in the switch-driver/current-regulator circuit was reduced by modifying the coupling circuit between the first and second stages. Ringing on the output current was eliminated by replacing the series-tube/cathode-follower circuit with a conventional cathode follower.

(b) The waveshape of the write current was improved by adding a diode and a resistor across the primaries of all switch cores.

(c) The variation in bias current, that is a result of the resistance of the bias winding being a function of the temperature of the winding, was eliminated by connecting the bias windings of both core switches in series and replacing the voltage source that supplied the current with a current source.

(d) The switching characteristics of the feedback diodes have been stabilized by a modification to the switch-driver/input-amplifier circuit.

In addition, an investigation of the plane outputs showed that the noise on some sense winding sections was greater than the noise on other sections. Further study disclosed that the noise

*R.C. Johnston, "Transient Response of Junction Transistors," Report 6M-4913, Part I; Report 6M-4913, Supp. 1, Part II, Lincoln Laboratory, M.I.T.

was induced by the inhibit currents in other planes in the stack and coupled to the noisy plane via selection drive lines. No correlation could be obtained between the wiring configuration and the magnitude of the induced noise. However, the noise in the questionable planes was reduced to a level equivalent to that of an average plane by connecting a small capacitor externally from one side of the noisy sense winding section to ground.

Operation of the 256^2 memory has been very satisfactory since the above circuit changes were made.

2. Transistor-Driven Core Memory (TDCM)

The TDCM is being wired with the 50-mil OD, 30-mil ID ferrite cores. A 64 × 64 mold for a positioning jig for these small cores has been delivered by Group 60 (see Sec. IX, B. 1., this report) and a number of jigs have been pressed.

Several designs for read/write gate generators have been breadboarded and tested. However, a decision on the final design has not yet been reached. The address-decoder plug-in units have been tested.

A prototype welding machine has been constructed and tested for butt-welding 4- or 5-mil copper wire to 6- or 8-mil steel needles for use in wiring the TDCM memory planes. The salient features of the machine are an optical system for positioning the wire and needle, a capacitor discharge system to supply the welding current, and a spring mechanism to control the rate of travel during the welding operation. The diameter of the finished weld is larger than the diameter of the wire and smaller than the diameter of the needle. The prototype (see Fig. 63-4) is already welding needles used in the construction of TDCM planes. The initial design has been turned over to Group 60, General Engineering, for fabrication of a final model.

Fig. 63-4. Prototype machine for butt-welding hollow steel needles to copper wires for new small core memories. Insert shows 4-mil copper wire welded to 8-mil hollow needle 85× enlarged.

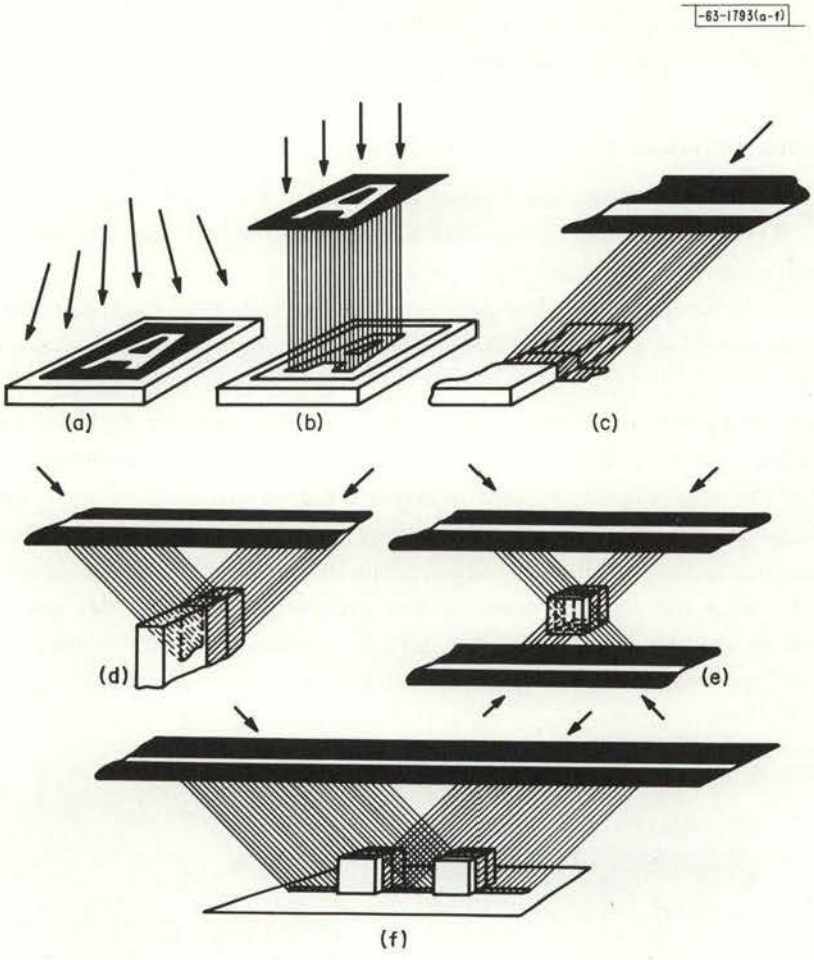

Fig. 63-5. Printed wiring exposures using random and collimated light.

3. Print-Wired Memory Planes

A method has been developed for producing three-dimensional etched wiring as a result of the studies on print-wired, ferrite-core, memory planes for digital computers.* Collimated light is the basis of the new technique, which can be combined with commercial photographic methods of producing printed wiring.

A laminate, clad on one or both surfaces, is the usual material used to support etched wiring. This material is satisfactory for most applications, but has the disadvantage that conductors are confined to the clad surfaces. This limitation is removed by chemically and electrically depositing copper over the entire board. Instead of the standard "contact" photographic exposure of acid "resist," an exposure is made by passing collimated light through planar masks that are negatives of the conductor patterns.

Figure 63-5(c) illustrates the manner in which a three-dimensional pattern is exposed, developed from the conventional two-dimensional method shown in Fig. 63-5(a), through the method using parallel rays shown in Fig. 63-5(b). The exposed area in Fig. 63-5(b) is the same, regardless of the separation between the lamp, mask, and the board, as that in Fig. 63-5(a), affording no particular advantage. However if a beam of collimated light is directed at an appropriate angle, a conductor can be printed around a corner in three dimensions as in Fig. 63-5(c). A continuous conductor from one side of a board to the other can be exposed by using two sources of collimated light as shown in Fig. 63-5(d). A conductor can be printed completely around the board by combining four sources of collimated light and two planar masks as in Fig. 63-5(e). A conductor pattern can be exposed anywhere on a three-dimensional surface by suitably directing the collimated light as shown in Fig. 63-5(f).

Parallels and meridians were projected on the surface of a ping-pong ball to demonstrate the feasibility of this collimated light technique as shown in the photographs, Fig. 63-6. In Fig. 63-6(a), the ball is placed midway between the parallel planar masks and each quadrant of the sphere is illuminated by a separate source of light projected at a 45° angle to its planar mask. One-half the setup is shown in Fig. 63-6(b) for further illustration. Inductors can be similarly exposed. Figure 63-7 shows such a coil and its mirror image and Fig. 63-8 shows the complete setup used to expose the coil. Figures 63-9 and 63-10 are orthographic projections illustrating the method of producing planar masks for the sphere and spiral coil; Fig. 63-11 shows the method for exposing a toroidal coil. Figure 63-12 is a photograph of the beam shape resulting from the collimated light which, in order to expose windings on a toroidal form, must first pass through two conical lenses.

4. Thin Film Memories

A memory system with a storage of 256 to 1000 words and a cycle time of 0.5 μsec is a first goal of the thin-film studies being made in the memory laboratory. A new evaporation system was installed during the quarter and will evaporate films specifically for engineering study.

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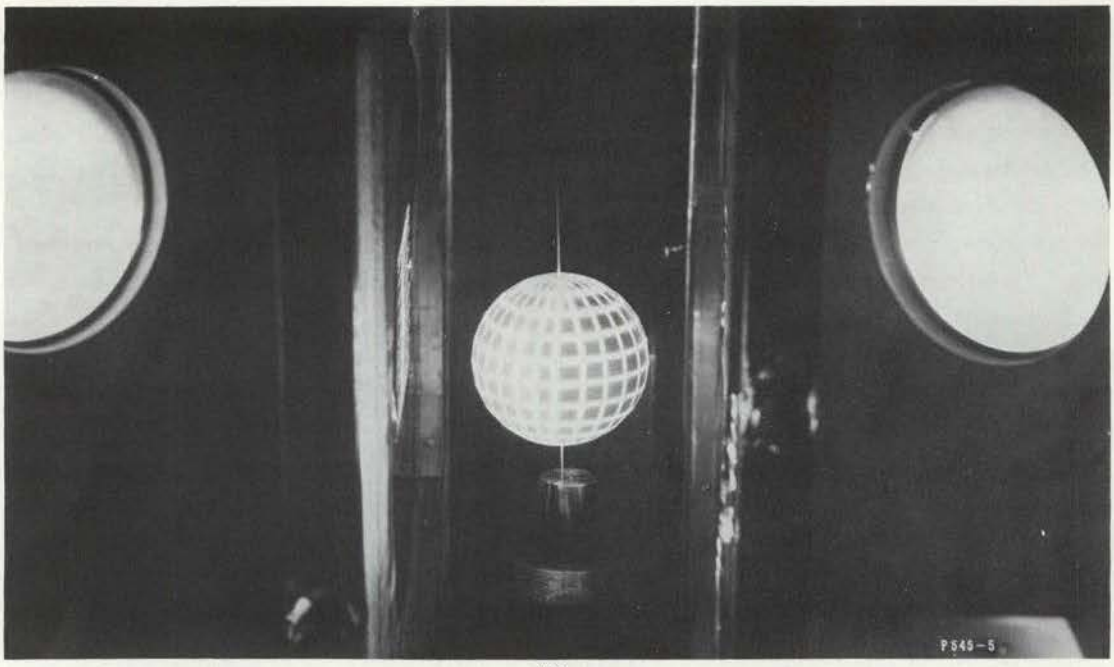
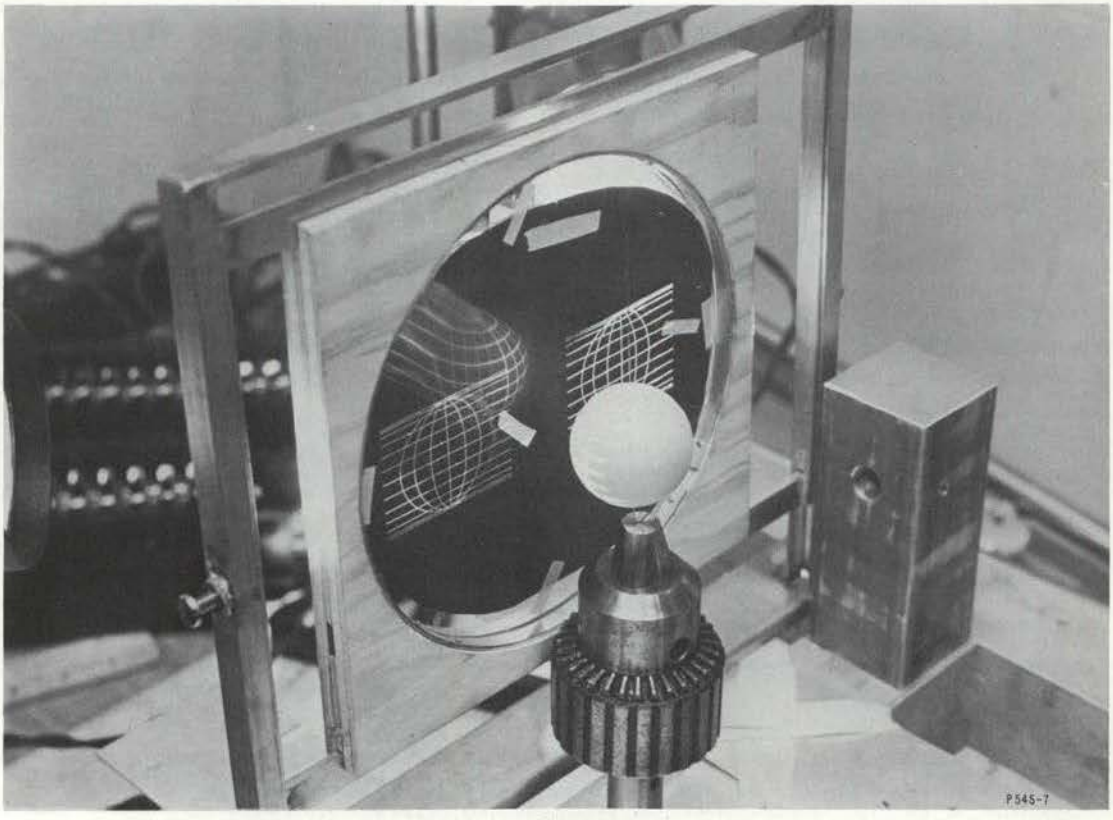
*Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 December 1956), Sec. III.D.4, pp. 34-36; and E.A. Guditz, "Three-Dimensional Printed Wiring," Electronics, June 1, 1957 (pp. 160-163).



(a)



(b)

Fig. 63-6. Parallels and meridians exposed on spherical surfaces using the collimated light technique.

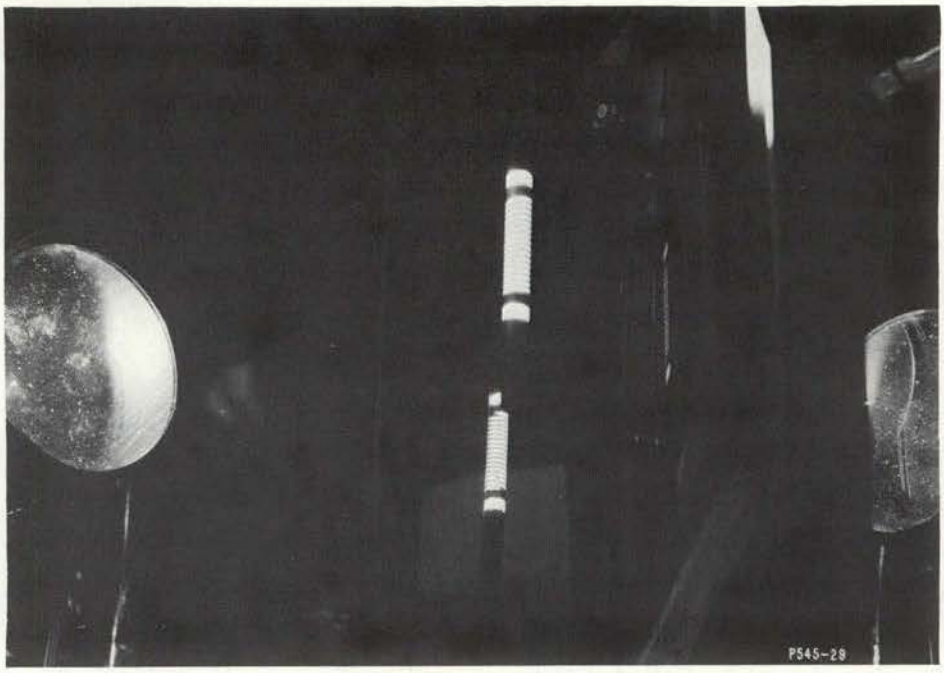


Fig. 63-7. Inductance coil exposed using collimated light technique.

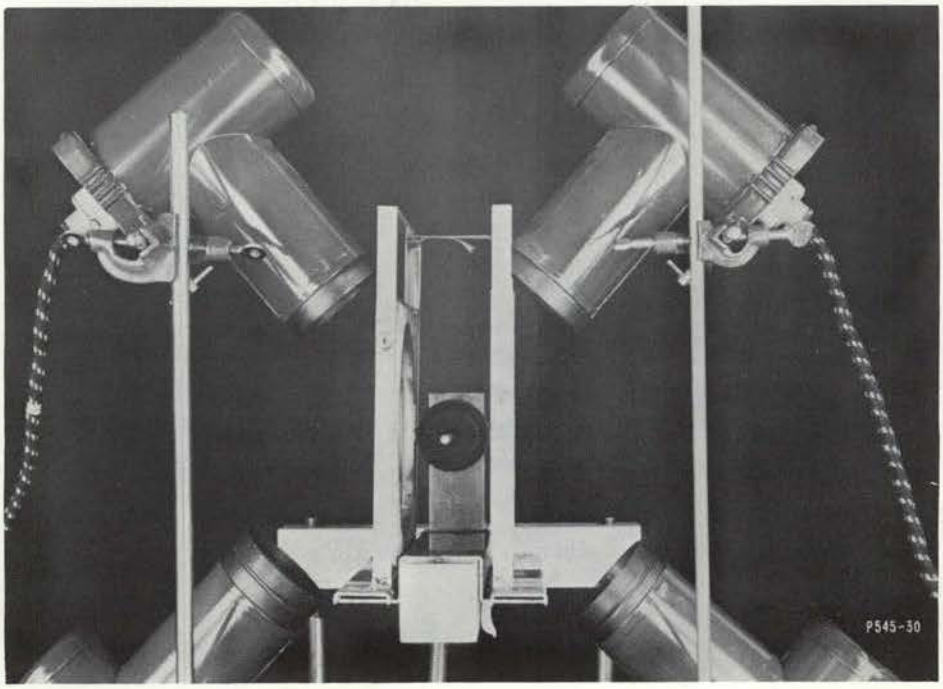


Fig. 63-8. Setup used to expose inductor coil.

GROUP 63

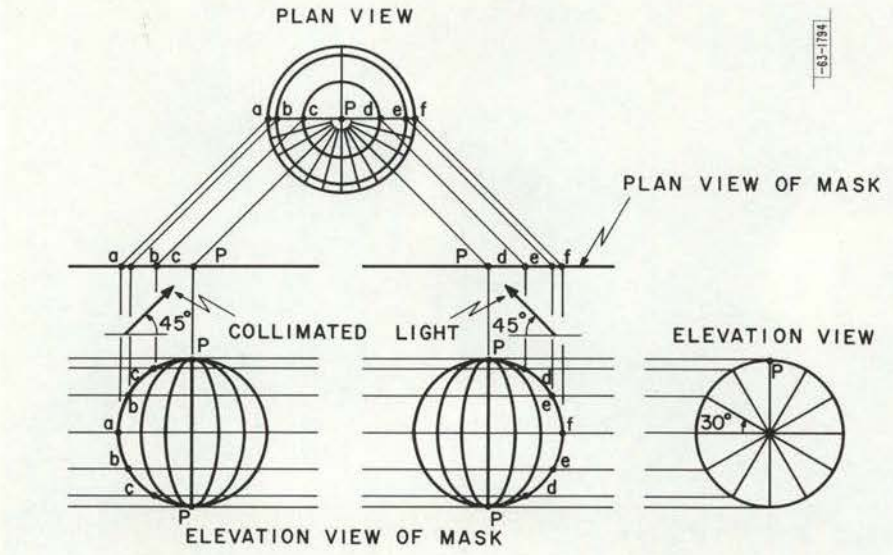


Fig. 63-9. Method of mask generation by orthographic projection.

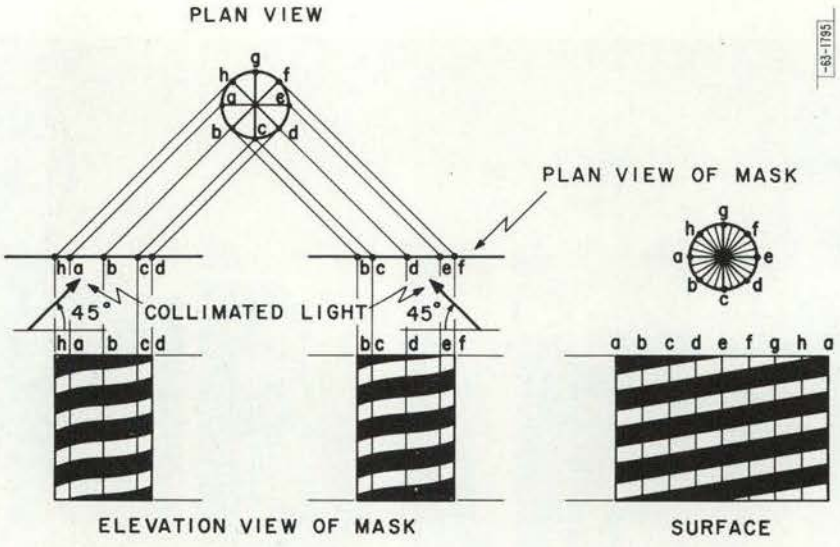


Fig. 63-10. Mask for inductance coil generated by orthographic projection.

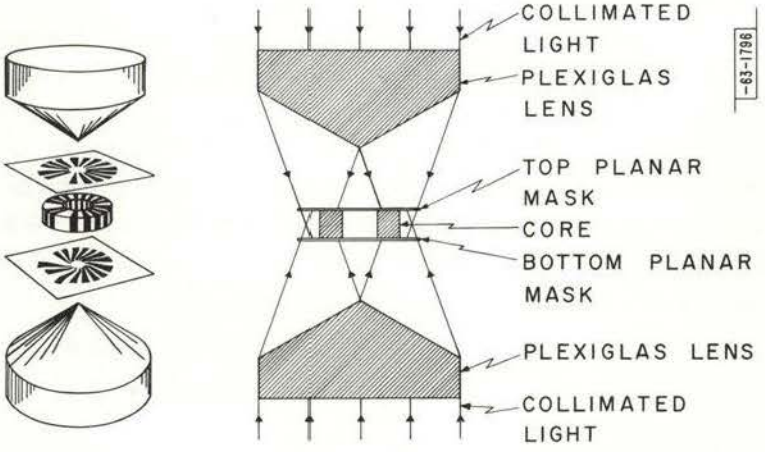


Fig. 63-11. Projection of printed toroidal windings.

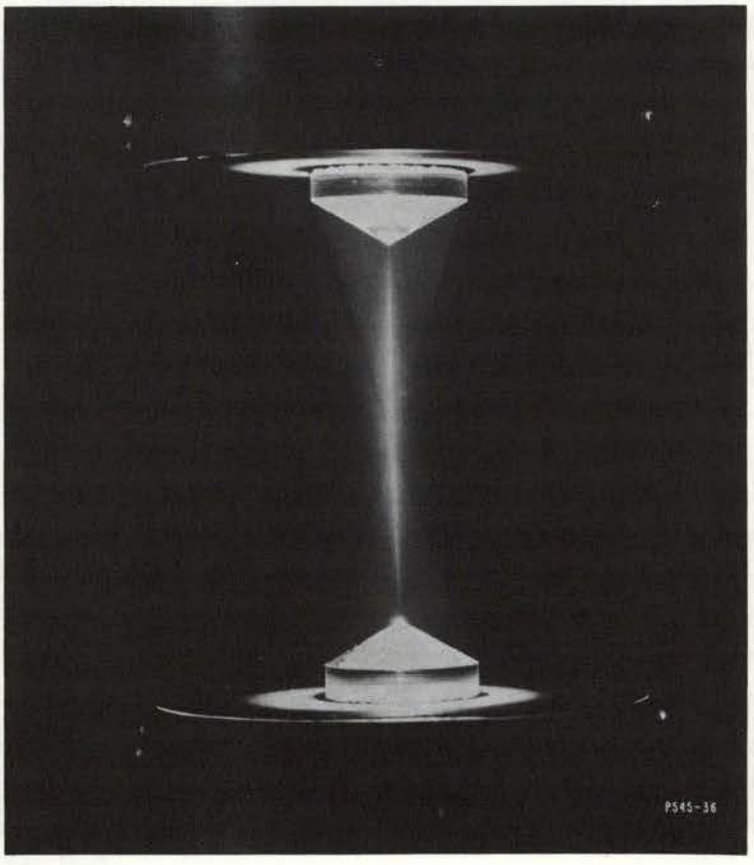


Fig. 63-12. Beam shape of collimated light passing through two conical lenses used to expose toroidal windings.

Several 5 × 5 arrays of spots were deposited and showed fair uniformity within a run. An occasional spot may differ greatly from its neighbors, but there is no clear indication yet as to why; nor is there any indication why runs will vary under apparently identical evaporation conditions.

Single spots are being tested on the low-frequency hysteresis-loop tester and with crossed drive lines under pulsed conditions. The drive lines are presently made of fine magnetic wire imbedded in slotted Plexiglass, rather than by printed circuit techniques. Design of a unit for testing small arrays is being considered. A survey is being made of transistors that might be used for driving films. Some test circuits are planned using 5134's and 5409's. The 50-30 mil ferrite cores are also being tested as possible switch cores for driving. Several selection systems are being evaluated in an effort to determine the most desirable type for a thin-film memory.

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J. Raffel

E. TERMINAL EQUIPMENT

1. XD-1 Displays

Several attempts have been made to eliminate the curvature of vectors and smearing of E-characters that still plague the situation display consoles in Building F. The trouble is definitely caused by noise on the digital-data lines that supply signals to the digital-to-analog decoders within the console. The only method tried that did eliminate all visible curvature and smearing would be costly in terms of both the components of the additional circuitry and the modifications to the situation display frames that would be required. Studies are in progress to find an alternate, less expensive solution to the problem.

2. Remote Display

The remote display system being developed* will provide, via telephone line, a duplicate at any external site (such as a radar site or an airbase) of the situation display seen in a direction center.

The remote-display console frame has been completed and is now running with a standard Charactron. The new storage Tonotypotron is expected about the middle of June, when exhaustive testing of the system will begin. At present, the frame is operating satisfactorily, but since no storage facilities are available in a Charactron, the display is not flicker-free. A special test-signal generator is supplying a limited programmable display but, for final testing, signals will probably have to be generated at Whirlwind I and brought here via telephone line.

3. Whirlwind I Display

Excessive noise and slow rise time have long been a problem in the Whirlwind I display system. Tests are under way to determine the degree of noise rejection and the best possible rise time for a satisfactory display.

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W. F. Santelmann, Jr.

*Quarterly Progress Reports, Division 6, Lincoln Laboratory, M.I.T. (15 September 1956 to 15 March 1957), Sec. III. D.

F. TX-0 AND TX-2

1. Equipment Installation

The TX-2 frame was assembled and modified to include facilities for power, pulse, and in-out wiring. The major power supplies were delivered, installed, and temporarily wired to the frame to provide power for testing the registers (Fig. 63-13). Registers A, B, C, D, E, F, M, N, P, Q, X, the X-adder, and the X-memory system were mounted on the frame, their back-panel wiring was partly completed, and inter-register wiring was begun. Many of the transistor plug-in units were delivered but further testing is required before they can be used. It was determined that the usual RG62U coax cables and BNC connectors could not be used to wire the frame to the in-out equipment and the several memory systems. Therefore, a cabling system was designed and ordered which uses a special small coax cable, bundled in groups of ten, and terminated in the standard 18-pin connectors that are used for the transistor plug-in units.

The air conditioning system of TX-0 gave considerable trouble this quarter due to faulty compressors and control circuits. After the compressors were repaired and reinstalled in the system, the control circuits were balanced. No further trouble has been experienced or is expected.

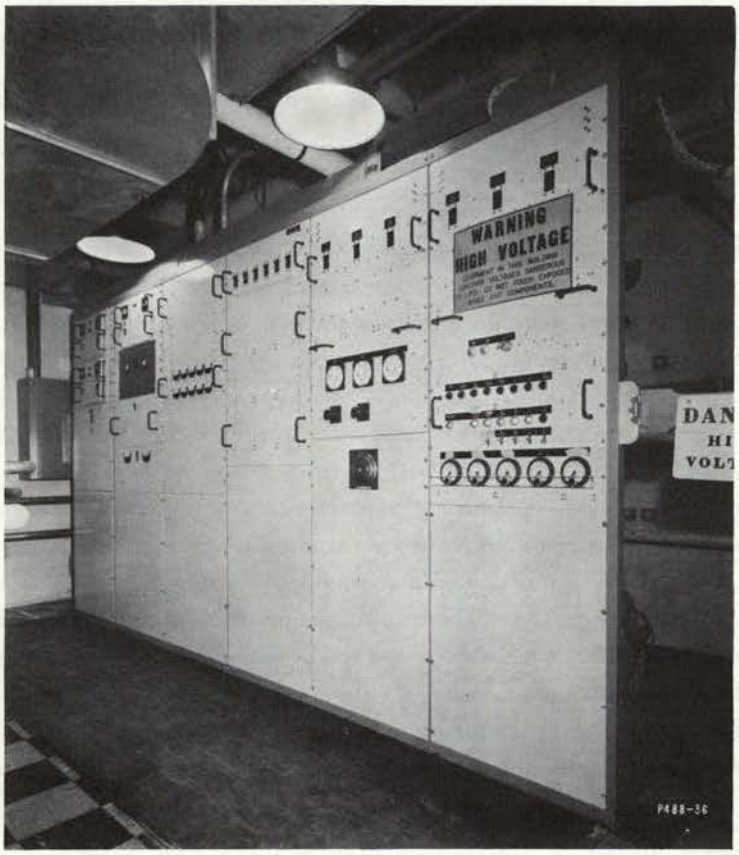

Fig. 63-13. TX-2 power supplies.

The new control system* for the TX-0 and the new TX-2 power supplies was completed and installed during the quarter. Operation was satisfactory. Parts of the display system* were moved to the control console. Final models of the amplifiers and decoders were built as well as a control for the display system power supplies.

Many surface-barrier transistors were removed from TX-0 and sent to the Transistor Section (see Sec. III, C. 1. of this report) for retest to determine the extent that the parameters have degraded under the operating circuit conditions experienced in TX-0.

An important addition made to TX-0 during the quarter consists of an Epsco Datrac high-speed analog-to-digital converter and its associated control equipment. Datrac will, at the command of the computer, sample an analog voltage input to the converter, convert it to a binary number, and place it in the computer's live register, at the rate of 10,000 samples per second with 9-bit accuracy. The system has converted and stored in the memory an operator's voice and played it back through TX-0's audio decoder system with good fidelity.

2. Magnetic Tape Bulk Storage for TX-2

A mechanically simple magnetic tape handler is being developed for TX-2 that is a radical departure from previous digital tape handlers. The conventional approach stresses quick start and stop times, accomplished by passing the tape over two oppositely rotating capstans, each of which has an associated solenoid-operated punch roller. When a solenoid is energized, the punch roller presses the tape onto the rotating capstan, causing that capstan to drive the tape. The takeup reels must be servo-controlled, with the direction and speed of rotation of each reel determined by the amount of tape in the takeup loop between the capstan assembly and the takeup. The record-playback head is usually located between the capstans. The mechanical complexity in this conventional system results in considerable maintenance.

Two conventional 1/8 hp, 3-phase, squirrel-cage motors will each be connected directly to a takeup reel to form the basis of the new drive system. Two guide pins, two heads, and two direction-sensing switches will complete the assembly. Start and stop times will be very slow compared to conventional machines, but a high-speed search mode will be available. Voltages proportional to the desired torque will be applied by 3-phase magnetic amplifiers. Each motor will be able to generate torque only in the direction corresponding to the tape windup on its own reel. For high-speed search, one motor will have maximum voltage applied and will accelerate until it approaches its synchronous speed of 1800 rpm. For controlled, low-speed operation, the frequency of the signal that is read from the tachometer track is used to control the torque on the driving motor while the trailing motor has a constant low voltage applied to keep some tension on the tape. The tachometer track is prerecorded at constant density on a constant-speed machine, and is read by one head which does nothing else. The other head assembly reads and writes the information on the other tracks.

A variation of the non-return-to-zero recording technique is used which allows reliable playback at a wide range of tape speeds, thus making the high-speed search mode useful. A flux

*Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 March 1957), Sec. III.F.

change of one polarity is recorded for a ONE and a flux change of the opposite polarity for a ZERO. Playback information is contained in the polarity of the signal, all that is needed in the read amplifier is enough gain to give a satisfactory signal at the lowest tape speed to be used.

The simple mechanical system requires a relatively complex electronic system to make it perform. As a bulk-storage medium for TX-2, it is planned to have many of the tape handlers and only two sets of the circuitry. The circuitry would be switched (through mercury-wetted relay contacts) to the tape handler desired. The large number of tape handlers and the small number of sets of circuitry make this type of bulk storage attractive from the point of view of cost.

With a ten-track head and 1/2-inch tape complete redundancy will be gained by simply connecting pairs of nonadjacent heads in series, to give five channels. One channel will be used for the prerecorded tachometer track, one for timing, and three for data.

Encouraging results have been obtained from a breadboard model of the mechanical assembly and some of the basic circuits.

3. TX-0 Utility System

A direct-input communication system of programs has been written for the TX-0 computer.* The large 256^2 memory makes such a system possible and practical. Although basic in form, it is unique in the sense that it assists the programmer in debugging and modifying his program at the console.

The complete utility system, at present, contains over a dozen routines (see Fig. 63-14) which communicate in English with the programmer by means of a direct input-output typewriter. Questions and answers are typed on the same typewriter by the programmer and by the computer and may be English words or numbers, depending upon the nature of the questions asked. Although the programming language of the utility system has been restricted to absolute addresses and constants, the programmer is not restricted from writing his original program in relative form. The present English vocabulary of the utility system consists of 63 words. The system is controlled by a master routine called EXPEDITE, which acts as a translator and dispatcher. Its main task is to recognize requests for the various routines available, but it also acts as a subroutine when the other routines in the system require answers in English from the programmer. Whenever a word is received by EXPEDITE that is not listed in its vocabulary, the unfamiliar word is printed out as an error.

The major routines of the utility system, in addition to EXPEDITE, are:

(a)	TODAL	paper tape conversion of symbolic-addressed programs accompanied by a printed translation from symbolic to absolute form
(b)	HARK	direct input conversion of absolute-addressed programs
(c)	PRINCE	storage printout

*J.T. Gilmore, Jr., "TX-0 Direct-Input Utility System," Report 6M-5097, Lincoln Laboratory, M.I.T. (10 April 1957).

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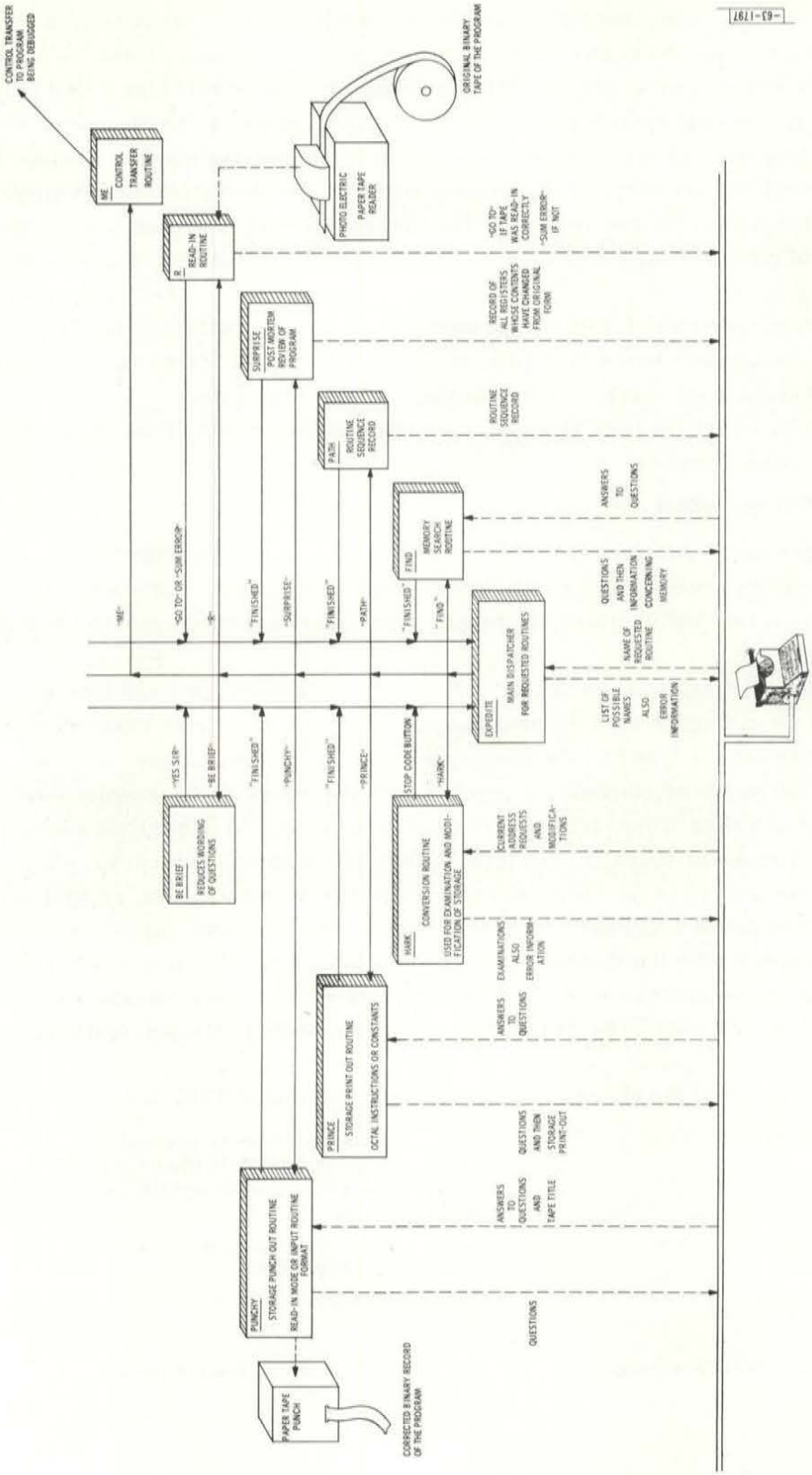

Fig. 63-14. Block diagram of TX-0 utility system of programs.

(d)	PUNCHY	storage punchout
(e)	R	read-in
(f)	SURPRISE	reviews and types out addresses of all registers whose contents have changed from their original form
(g)	FIND	finds incidents of redundancy resulting from combination of several programs in storage
(h)	FLOW CHART DISPLAY	displays on the oscilloscope the control path of the program being debugged
(i)	PATH	obtains a printed record of the sequence in which the sections of the program being debugged were performed
(j)	BE BRIEF	reduces questions in every routine to one or two words (once the programmer is familiar with the questions)

The utility system is very basic; it merely suggests a technique whereby a programmer can see what his program is doing, examine it, and modify it rapidly while he is still at the console of the computer. Some improvements in the system (for TX-2) will include the following:

(k) A logical scheme associated with the flow chart display.

(l) The paper-tape conversion routine, TODAL, will inform the programmer of any illegal word on the typewriter tape and ask whether he wants the conversion process to be continued with the illegal word ignored or corrected. Corrections would be made via the direct-input typewriter.

(m) The direct-input conversion routine, HARK, will understand both absolute and symbolic-addressed programming language.

(n) Both the paper tape conversion program, TODAL, and the direct-input conversion routine, HARK, will provide a facility for inserting or deleting instructions, will then readjust the program, and print a new symbolic-to-absolute translation (via the high-speed printer).

(o) A check routine will make a sum check on all permanent instructions and constants in the utility system to assure that the utility system has not been damaged by the program being debugged.

Not only does this system of utility programs allow the programmer to find the mistakes in his program and correct them, but it also allows him to change parameters and write additional routines to his program, thereby using the computer as an immediate and flexible tool on which to try out new ideas while they are still fresh in mind.

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B.G. Farley J.T. Gilmore
J.W. Forgie H.P. Peterson

ESS SHAKEDOWN TESTING – WWI AND MTC OPERATION

GROUP 64

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IV. ESS SHAKEDOWN TESTING – WWI AND MTC OPERATION
GROUP 64

A. SUMMARY

Testing of the Experimental SAGE Sector this quarter saw the introduction and conclusion of tests using Package B, the air surveillance portion of the Direction Center Active (DCA) Program. The functions added in Package B are automatic initiation, track monitoring, height-finding, manual inputs, and identification. Analysis of test results established that the functions contained in the package conform in all major respects to the specifications, and that testing with Package D can begin on schedule in June. The Memory Test Computer (MTC) continued its support of ESS system shakedown testing by reducing test data for analysis and producing simulated-data-generation tapes, while at the same time undergoing extensive equipment changes. The efficiency of Whirlwind I (WWI) was increased by a high-speed line printer and by the reduction of the block transfer time from drum to core memory.

During a regularly scheduled ESS shakedown test in which only the functions of Package A were in use, 34 B-47 type aircraft flying a Strategic Air Command mission were tracked across the sector with 81 per cent track life efficiency – a favorable performance under the conditions imposed by the surprise nature of the raid. A total of 36 regularly scheduled systems tests showed that the program, equipment, and operators performed satisfactorily. Emphasis was placed on operator integration through special exercises and improved procedures. Investigations were started to locate and eliminate small errors that were detected in the overlap tracking and height-finding functions. A library was completed which combines basic data reduction programs, and a new program was in preparation which will measure the tracking accuracy of the DCA program.

The MTC section, in addition to fulfilling its function of reducing ESS test-data for analysis and producing simulated-data generation tapes, continued extensive installation, replacement, and revision of equipment and circuits in order to improve the reliability of the computer. A training program for MTC personnel was begun, consisting of one hour of instruction per week, to promote improved operation and maintenance of the computer.

A high speed line printer was added to WWI and circuit modifications were made which reduced the time required to transfer blocks of data from drum to core memory. Four teletype output circuits have been installed and tested between WWI and four airbases: Otis, Weymouth, Hanover, and Hanscom. High operating margins have been achieved on all four AN/FST-2 input channels from Bath and South Truro.

E. S. Rich
N. L. Daggett

B. ESS SHAKEDOWN TESTING

1. General Plan

ESS equipment, computer programs, and operators are combined in a series of system shakedown tests to produce data for the diagnosis and correction of any faults that may indicate lack of compliance with specifications. Particular air defense functions are examined in each

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TABLE I
ESS SYSTEM TESTS PERFORMED WITH PACKAGE B
(1 March to 31 May 1957)

Test No.	Standard Input Data	Times Performed	Primary Functions Tested	Primary Objective Met
6A*	Mixed	2	Air surveillance, using live radar data from long range sites and simulated aircraft	Yes, in 1 test No, in 1 test
7	Simulated	5	Track monitoring, identification, operator training, track detection and initiation, automatic tracking, and TBS	Yes, in 3 out of 5 tests
8	Ampex	4	Overlap tracking	Yes
9	Live	4	Similar to #7 and #8 but using live radar inputs; radar mapping added	Yes, in 2 tests Partly, in 2 tests
9A	Mixed	1	Back-up for #9	Yes
11	Live	3	Height-finder, using live radar data	Yes, in 1 test Partly, in 2 tests
11A	Mixed	2	Back-up for #11	Yes, in 1 test Partly, in 1 test
12	Mixed	2	Radar inputs including gap-filler radars	Yes
12A	Mixed	2	Same as #12 but using aircraft participating in Cape Cod System Tests	Yes
13	Mixed	2	Same as #12 but using different flight paths	Partly, in 1 test No, in 1 test
S4	Simulated	1	Switch and light gun functions in TBS and air surveillance rooms	Yes
S5	Simulated	2	Automatic tracking around turns	Yes
OIST-1	Simulated	1	Modification of test #7	Yes
OIST-2	Simulated	2	Modification of test #7	Yes
OIST-3	Simulated	1	Modification of test #7	Yes
Special	Mixed	1	Overlap tracking	No
Special	Ampex	1	Overlap tracking	Yes

*Package A tests.

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TABLE II
BREAKDOWN OF ESS TESTING TIME

Functions	Dec. – Feb.	Mar. – May	Mar.	Apr.	May
No. of test periods	32	36	13	9	14
	Per Cent of Total Test Time				
System operation	68.8	57.4	56.9	52.2	63.0
Equipment checkout	1.3*	3.0	5.6	3.2	0.3
Start-stop procedures	4.0	9.4	8.4	11.5	8.2
Program trouble	1.0	1.6	4.9	0.0	0.0
Equipment trouble	22.1	25.8	22.8	27.8	26.9
Miscellaneous lost time	2.8	2.8	1.4	5.3	1.6
	100.0	100.0	100.0	100.0	100.0
Interrupting failures	87	43.7	52	32	47
Mean free time† (minutes)	60.0	46.2	38.9	55.0	44.7

*Not tabulated for December 1956.
†Total time less program trouble and equipment trouble divided by interrupting failures.

system test as the computer programs for them become available. The tests become more comprehensive and more complex as each package of the DCA program is received from Group 67. Thirty-six system tests were performed during the quarter; thirty-four used Package B which was delivered on 3 March. The tests performed are briefly described in Table I and a breakdown of ESS system testing time is given in Table II.

The functions included in Package B of the DCA program are:

Radar Inputs
Manual Initiation
Automatic Tracking
Data Simulation
Recording
Automatic Initiation
Track Monitoring
Height-Finding
Manual Inputs
Identification

2. Test Implementation

The functions called for in Package B required an increase of 10 Air Force operators, making a total of 38 engaged in ESS system testing. Increased attention was paid to the integration of these operators:

(a) Eight operator integration shakedown tests (OIST) are called for, of which three have been performed; each of the three is a modification of test #7 and is composed of two hours of simulated data.

(b) Greater emphasis was placed on briefing and debriefing the test crew; observer scripts were improved in order to make debriefing more effective.

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(c) Work proceeded on eleven ESS operator handbooks which will describe the operator's duties and standard operating practices for each type of operating position; this was a cooperative effort with AFCRC (6520th AC&W Squadron) and ADC (4620th Wing).

(d) Consideration was being given to the feasibility of using the mission history and station log to prepare an operator integration shakedown test analysis (OISTA) in order to improve both the OIST problems and operators' performance.

Beginning in April the Air Movements Identification Services (AMIS) of East Boston and New York were used as sources of flight-plan information; data from these sources was inserted through the manual inputs equipment. Because of the small volume of traffic entering the ESS from the New York control area, the input from the New York AMIS was temporarily suspended. It has been concluded that adequate testing of the identification function can be accomplished by using the East Boston input alone.

Two test periods were devoted to operation with specially planned radar data inputs in order to obtain computer-recorded track data for quantitative analysis of the registration of overlap data.

3. Test Results

a. Summary

Testing of the air surveillance portion of the DCA program, Package B, was begun in March and concluded in May. Preliminary appraisal of the test indicated that the functions perform as specified with no major deficiencies. Special emphasis was placed on the height-finding function, the registration of overlap radar data, and on the training and integration of operators.

Thirty-six system tests were performed: 13 in March, 9 in April, and 14 in May. The tests performed are listed in Table I, and a breakdown of testing time is given in Table II.

Basic data-reduction programs were combined into a data-reduction utility library. A tracking accuracy program now being written will provide a comparison between track paths as recorded by the DCA program and track paths as reconstructed from correlated radar data.

b. Analysis of System Functions

(1) Radar Inputs and Overlap Tracking Accuracy

System tests have made use of data from search, Mark X, and height-finder radars in South Truro and Bath. During May preliminary use was made of four ESS gap-filler radars and the Montauk long-range radar. Gap-filler inputs were found to be generally compatible with the DCA program and tracks were carried by the program on the data received; a qualitative evaluation of the gap-filler function awaits further testing.

Performance of the system in tracking with overlap data showed that for straight line tracks, data from both radars usually falls within the small search area and is correlated. At present the principal difficulty in system use of overlap data is the generation of false splits as tracks travel around the turns and data from one of the radars is shifted outside the small search area (see Fig. 64-1). Test data is being further examined to determine whether the automatic split detection logic is too sensitive under these conditions.

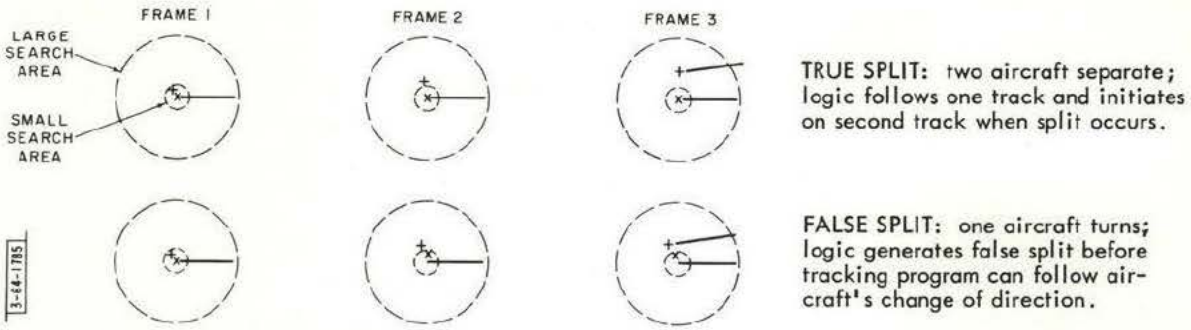
FRAME 1
FRAME 2
FRAME 3
LARGE SEARCH AREA
SMALL SEARCH AREA
TRUE SPLIT: two aircraft separate; logic follows one track and initiates on second track when split occurs.
FALSE SPLIT: one aircraft turns; logic generates false split before tracking program can follow aircraft's change of direction.
3-64-1785

Fig. 64-1. The large and small search areas are circles of five and one mile radius, respectively, used in the program but not displayed. The vectors (——) display the course and speed of the tracked aircraft.

The measured registration error between the Bath and South Truro heavy radars averages less than 1/2 mile. Detailed investigations have been made of radar orientation, sighting, and calibration errors, and of program coordinate conversion errors, and thus far indicate only small discrepancies, if any, in the quantities checked.

(2) Initiation

The automatic initiation program is designed to examine radar data in the area specified on the area discriminator and to form tentative tracks when data satisfies certain criteria. Tentative tracks may become established tracks automatically if subsequent data satisfies additional criteria, or they may be established by manual action on the part of track initiators.

A number of problems relating to the use of the automatic initiation feature have been overcome during Package B testing. Qualitatively, the feature now functions well; quantitative analysis will be made during Package D testing.

TABLE III
TESTS SCHEDULED WITH PACKAGE D

Test No.	Input Data	Primary Functions to be Tested
14	Simulated	General test to introduce weapons direction functions
15	Simulated	Intercept direction, intercept simulation, and operators
16	Live	External facilities such as interceptor airbases, weather stations, and AAOC
17	Live	Same as #16 but inputs more complex
18	Mixed	General test for weapons direction
19	Mixed	Similar to #18
20	Live	Full-scale comprehensive tests of entire system (concludes phase 1 of testing)
21	Live	Similar to #20

Sufficient data on the function of manual initiation has been analyzed to permit a final conclusion that design specifications have been met. Calculations of the range of initiations from the nearest long-range radar site were made for 153 tracks which penetrated the ESS coverage in the manner of strike aircraft. The calculations showed a mean range of initiation of 152 nautical miles. With respect to the accuracy with which track initiators can identify tracks and estimate course and speed from the data presented to them, an analysis showed that approximately 95 per cent of the initiations tried were successful. Initiations on noise data were made in only 18 out of 950 initiation actions; this means that noise data was mistaken for track data by the initiators in only 1.9 per cent of the initiations.

(3) Track Monitoring

The track monitoring position is one of the more complex operator positions in the direction center because it requires considerable human judgment in the choice of actions. In the initial stages of shakedown testing, the track monitors were somewhat confused, but after special coaching during test periods they were able to carry out their function under light loads. Training of these operators will continue until they can handle normal loads proficiently.

(4) Height-Finding

The height-finding function was tested five times during the quarter. The primary purpose of the height-finder is to provide the altitude of aircraft being tracked by the system. In addition, it provides information on the number, formation, and separation of aircraft in a flight. In the study of the height-finding function it was found that several difficulties had to be overcome before satisfactory results were obtained: The program did not sense for a zero flight size which is necessary to distinguish a null reply from a good one; requests sent out on tracks having poor track data resulted in an excessive number of null replies since the height-finder could not see the target; successive requests on the same track were sent too frequently; the Package B program does not distinguish between real and simulated tracks in sending height requests. Although the time required to diagnose and correct the discrepancies has prevented collection of much pertinent performance data, that which is available indicates that the accuracy of the height information derived from the system falls within the specified limits. Since some of the program corrections involving the height-finding function will be available when Package D is delivered, verification of this function will be continued.

(5) Manual Inputs and Identification

The manual inputs and identification functions in Package B of the DCA program have been tested together. Aircraft flight plans, inserted by means of manual inputs facilities, have been used for carrying out identification by obtaining correlation between flight plans and track data. Analysis of a relatively small sample of data indicates an average time to identify of 1 to 2 minutes. This time appears to be reasonable, considering the present stage of testing, and further improvement is expected. The analysis also showed that a high percentage of the total tracks carried were identified automatically; this facility is therefore valuable in reducing the workload on the operators.

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(6) System Performance During Special SAC Mission

During a shakedown test on 8 March, 34 B-47 type aircraft flying a Strategic Air Command mission passed through the sector. The ESS test personnel had not been informed in advance of the SAC mission and since Package A was being used for a special test, the DCA program functions of automatic initiation, track monitoring, height finding, manual inputs, and identification were not available. Data from two long-range radars, South Truro and Bath, was being fed into the computer. Analysis of data recorded during the 1-3/4 hour period in which the SAC mission was followed has given some significant results. Thirty-seven tracks were carried which followed similar courses and which had speeds consistent with those of B-47 type aircraft.

The tracking accuracy of the system during this mission was very satisfactory. The average track life was 34.8 minutes; this corresponds to a distance of 230 nautical miles at the speed flown by B-47 type aircraft. It is estimated that a track life of 50 minutes might have been achieved had the track monitoring function been available for use on those tracks which might logically have been aided by it. A track life of 50 minutes corresponds to a distance of 330 nautical miles at the speeds flown. When the sum total of path lengths over which the aircraft were tracked automatically is divided by the sum total of possible path lengths extrapolated from ESS border to border, the quotient is 81 per cent – a track life efficiency which compares most favorably with both the existing air defense system and the Cape Cod System.

c. Support Programs on MTC

Basic data reduction programs have been combined into a data reduction utility library. The programs have been recorded on a single magnetic tape to provide a convenient and flexible means for selecting any desired sorting, display, or other utility program which is needed in the reduction of test data. A major portion of the programming effort in this quarter was given to the writing of a tracking accuracy program which will provide a comparison between track paths as recorded by the DCA program and track paths as reconstructed from correlated radar data.

Planned modifications and additions were on schedule to make the data reduction and simulated data generation programs compatible with the requirements of Package D of the DCA program.

C. C. Grandy	Nancy Hudson	N. T. Jones
C. S. Lin	R. F. Hudson	E. Lafferty
J. C. Hodder	D. J. Thomas	J. Monahan
W. Ogden, Jr.	M. D. Black	J. R. Nichols
J. J. Cahill, Jr.	R. D. Buzzard	P. Stylos
A. Vanderburgh	D. R. Aufderheide	W. Woodward
Emy Brooks	H. P. Bridge	H. F. Mercer
Carol Chomsky	Jean C. Bryan	J. Roberts
Lois Earl	A. W. Case	T. A. Roberts
Virginia Fitzpatrick		

C. MEMORY TEST COMPUTER

MTC is reducing test data and producing simulated-data-generation tapes in support of ESS shakedown testing. It is also used for SAGE simulation studies being conducted by Group 22.

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During this period, continued emphasis was placed on improving the reliability of the computer. Examples of these efforts are given below.

1. Power Supplies

Two new 150-volt power supplies were tested under full load and installed. Power supplies at the following voltages either have been completed or will be completed in the near future: +10 volts, −30 volts, −300 volts, and +250 volts. A −15 volt power supply is currently in the design stage, and a +90 volt power supply is under consideration.

2. High-Speed Paper Tape Punch

A high-speed paper tape punch was received from Soroban Engineering, Inc. This input-output device now makes it possible to read in or out of the computer at the rate of 200 characters per second, roughly 17 times the speed of the Flexowriter previously used. The high-speed punch will be put into operation upon completion of a mounting panel and tape feeding device.

3. Improved Training and Organization

Plans were completed for a training program consisting of one hour of instruction per week for MTC staff and technicians. A service manual was begun which will serve as a standard guide to servicing procedures. The section was reorganized into three specific subsections with responsibilities as follows:

(a) to maintain the central computer together with the type and quantity of external devices normally made available to users,

(b) to train the MTC section,

(c) to be responsible for the redesign of unsatisfactory portions of the computer and for such new equipment as may be desired.

4. MTC Operation

MTC operation and reliability for this quarter measured over two-week periods, are as follows:

Scheduled computer hours	1918
Interrupting incidents	314
Hours lost	265.6
Per cent good time	85.5
Mean time between failures (in hours)	7.4

H. L. Ziegler
A. D. Hughes
D. Decof
N. J. Ockene
S. C. Olsen
C. E. Small
T. C. Stockebrand

D. CAPE COD ENGINEERING

1. Increased Efficiency of WW I

a. High-Speed Line Printer

A high-speed line printer was delivered on 17 May. Preparations for installing the equipment had been in progress for several weeks and programs for checking out the equipment had

been previously prepared. Initial testing indicated that data can be printed out directly from the computer in approximately half the time that would have been required to record on magnetic tape for delayed printout.

b. Reduction of Block Transfer Time, Drum to Core Memory

In WWI the auxiliary drum is a storage medium to supplement the high-speed, random-access, core memory. A recent reduction of the cycle time of the core memory made it possible to reduce from 4 to 2 the drum interlace,* thus halving the transfer time from 68 msec to 34 msec per 2048 registers. A correlative benefit has been that 1500 more instructions can be performed per drum transfer.

2. Automatic Teletype Outputs

Teletype outputs have been installed to connect WWI to the four airbases, Otis, Weymouth, Westover, and Hanscom. The examination of test results showed that all four airbases received the transmitted information without error, and the system was successfully included in the daily marginal checking program. A final report, "WWI Automatic Teletype Output System," is published as 6M-5103.

3. WWI Operation

WWI operation and reliability for this quarter, measured over two-week periods, are as follows:

Scheduled computer hours	2012.1
Interrupting incidents	93
Hours lost	56.0
Per cent good time	97.2
Mean time between failures (in hours)	26.1

L. L. Holmes
E. K. Gates
D. F. Allen
L. D. Healy
D. A. Morrison
P. J. Murphy
L. H. Norcott
A. J. Rowe

*Interlace refers to the displacement of consecutively numbered registers so that they are not consecutively placed around the circumference of the drum, but are separated by other registers. An interlace of two causes consecutively numbered registers to be placed two registers apart; the drum is read therefore at every other register, requiring two revolutions to read out all 2048 registers.

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VACUUM TUBES

GROUP 65

Youtz, P., *Leader*

Clough, T. F.
Palermo, J. S.
Twicken, S.

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V. VACUUM TUBES
GROUP 65

A. SUMMARY

Stromberg-Carlson's production efficiency increased by 14.9 per cent during the current period. Only 102 Charactrons were delivered because of reduced demand at IBM and Hazeltine and the fact that Machlett has qualified as a second source. Twenty-nine acceptable Machlett tubes designated "Scriptrons" were produced during the period. Charactrons have accumulated an average filament life of 5235 hours in the 74 XD-1 display consoles compared to 5412 hours reported for the previous quarter. Twenty-three Charactrons were removed from the XD-1 with an average of 6331 filament hours compared to 16 removals with an average life of 6130 hours for the previous quarter. No Scriptrons have yet been installed in display consoles. Three prototype Scriptrons have been on life test for 3000 hours during which time one electron gun failed.

Typotron production at Hughes Products has been limited by the decreased demand. Machlett Laboratories, under contract with Hughes Products, has been setting up production facilities to qualify as a second source. Typotrons in the 94 XD-1 display consoles have accumulated an average filament life of 8872 hours, a 15 per cent higher average life than reported for the last quarter. Thirteen tubes were removed after an average life of 7421 hours. The distribution of failures was normal for tubes reaching end-of-life limits. The problem of gassiness in previously reported failures has been eliminated by increasing the impedance of the A_3 electrode voltage supply.

Although General Electric has corrected the production problem of microphonics in the low-powered twin-triode (6414), factory shrinkage, caused by the spread of plate characteristics, is still too high for quality tubes. Raytheon is also meeting delivery schedules on this tube, although amplification factor and the simultaneous centering of both plate currents continue to be major production problems. Sylvania and Bendix are both producing the dual-control gate pentode, 6888, at a satisfactorily high yield. For the first time, production of 5998's at Tung-Sol exceeds the demand and a reserve stock is now available at IBM, Kingston. Tung-Sol acquired Chatham Electronics and thereby eliminated the second source of this tube. Chatham has corrected their cathode-peeling problem. The Bendix study contract produced handmade sample tubes with electrical characteristics close to the 5998 except for the portion of the Ip-Eg curve between zero-bias and –65 volt bias. Bendix believes that the desirable characteristics can be achieved and manufactured by proper adjustment and design.

P. Youtz

B. DISPLAY

1. Charactron

a. Production

Stromberg-Carlson had improved its production efficiency 14.9 per cent with a realization rate of 81.3 per cent as compared to 70.5 per cent for the previous quarter. A sharp increase

in the rate was noted in April when, for the first time, the realization rate reached 90 per cent. Due to the reduced demand at IBM and Hazeltine, the production of acceptable tubes was cut back to a total of 102 tubes from the 187 tubes accepted in the previous quarter. The major production defects are expressed as a percentage of the total tubes tested:

screen quality	5.5%	grid emission	3.9%
beam uniformity	7.8%	leakage other than grid	7.3%
grid leakage	3.6%		

b. Life-Test Program

The Charactron life-test rack at Hazeltine will be sent next quarter to the newly formed Display Tube Group of IBM at Kingston for life testing of recent production tubes.

Ten display tubes continue on the life racks at Barta. Four 19-inch M.I.T. tubes with bariated-nickel cathodes have accumulated an average of 5085 hours. One M.I.T. oxide-coated cathode display tube has been operating for 18,121 hours. Five Stromberg-Carlson Charactrons have an average of 10,784 hours (four of these are between 12,000 and 13,000 hours). Some of these tubes are now operating near the IBM acceptance test minimum.

As of 1 June 1957 the 74 Charactrons in the XD-1 display consoles had accumulated an average of 5235 filament hours, slightly fewer than were reported for the previous quarter. The distribution of hours is given in Fig. 65-1. After an average life of 6331 filament hours, twenty-three Charactrons were removed from XD-1. Almost half of the failures were for low emission.

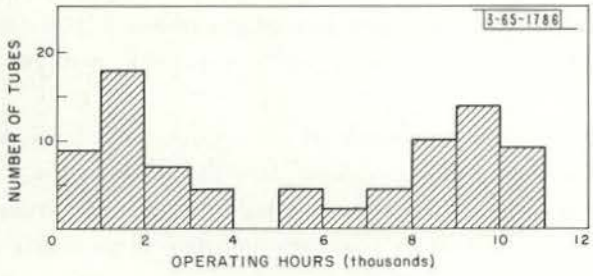

Fig. 65-1. Distribution of Charactron operating hours in XD-1 consoles.

Beam shift, a new phenomenon, accounted for a third of the failures for this quarter. It exhibits itself when either the intensity of the beam or the information repetition rate is changed. Many of the removals for beam shift also had low emission. Early next quarter it will be established whether the problem is an end-of-life phenomenon associated with cathode depletion or a problem in tube design and construction for the attention of Stromberg-Carlson.

c. Oxide-Cathode Studies

Thirty-nine tubes have been on life test to study different activation schedules and cathode materials for oxide-coated cathodes. Twelve tubes with an average life of 11,908 hours as of 1 June 1957 still pass cathode specifications similar to the IBM situation-display-tube acceptance tests. The tests have indicated that considerably more work must be done on vacuum techniques, processing schedules, and materials, if the life of an oxide-coated cathode in the Charactron is to be improved.

d. Bariated-Nickel Cathode Studies

Twenty-six tubes with bariated-nickel cathodes have accumulated an average life of 7,643 hours with no failures. Results of our B-N program are being compared with those of the

Raytheon group and other similar programs in this country and in Britain. When 10,000 hour data is available, the next step in the B-N program will be decided.

2. Typotron

The production of Typotrons at Hughes Products has been limited by Hazeltine to a fraction of rated capacity. Research on new types of storage media and convergence systems continued at the Hughes Tube Laboratories. They also had a very active program on the development of a 21-inch storage tube, the Tonotypotron, which is of interest to the display section of Group 63 for remote display work.

Seventeen early production tubes accumulated an average life of 14,490 hours on the life-test racks of Group 65.

Number of Tubes	Number of Hours
10	11,000 – 12,000
2	17,000 – 18,000
7	18,000 – 19,000

Seven of these tubes continued to meet all of the IBM purchase acceptance test specifications and the remaining tubes continue operable.

Hazeltine put some recent production Typotrons on their life test rack which was later dismantled and sent to the IBM-Kingston display tube group. The test will be continued at Kingston as soon as the life-test rack can be reactivated.

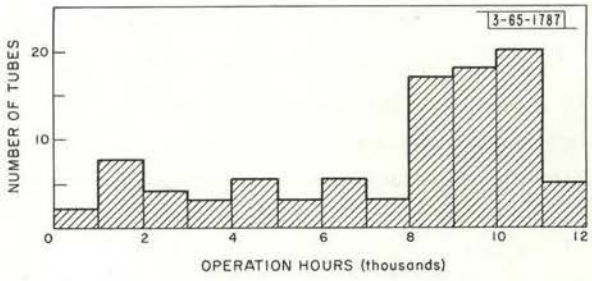

Fig. 65-2. Distribution of Typotron hours in XD-1, XD-2, and consoles being tested by IBM.

The 94 Typotrons in XD-1 consoles had accumulated an average filament-hour life of 8872 as of 1 June 1957 compared to 5999 hours on 1 March 1957. The distribution of hours is given in Fig. 65-2. Thirteen Typotrons were removed from XD-1 during the quarter with an average life before failure of 7421 filament hours. The failure results are summarized below:

Number of Tubes	Filament Hours	Stated Reason for Removal from Console
5	1055 1602 7907 7947 8975	unsatisfactory display
2	1807 8974	electrical leakage
3	4399	flood gun failure

The failure pattern was normal for tubes reaching their end-of-life limit. It is significant that no removals were due to gas which accounted for most of the failures the previous quarter. The gas problem was corrected by increasing the impedance of the A_3 voltage supply in the display consoles to reduce the current available to maintain an arc within the tube.

3. Second Source of Display Tubes

Machlett Laboratories of Springdale, Connecticut, is the qualified second source of situation-display tubes. They are operating under a license from Stromberg-Carlson and producing Charactron-type tubes under the trade name of Scriptron. At the end of this quarter they had made 60 acceptable tubes which passed all the test specifications at Hazeltine. The most serious production problem of the Scriptron had been peeling on the edge of the aluminum-dag band. This problem was solved after they adopted the processing procedure used by Group 65 for this tube type. Of the three Machlett Scriptrons which had been put on life test at Stromberg-Carlson for 3000 hours, two operated satisfactorily. At the end of this quarter no Scriptrons had been installed in the XD-1 consoles or production consoles.

Machlett Laboratories, under contract with Hughes Aircraft, was attempting to qualify as second source for the digital-display tube. Hughes has been giving them technical assistance in setting up their jigs, fixtures, and other equipment and facilities.

C. RECEIVER TUBE ENGINEERING

1. Low-Power Twin-Triode (Type 6414/0528)

a. General Electric Company

Recent shipments indicate that the microphonics problem reported in the QPR dated 15 December 1956 has been corrected. Although shrinkage due to the spread of plate characteristics was reduced during this quarter, it is not under adequate control. Once receipts at Kingston were adequate to meet SAGE requirements, the factory yield at G.E. improved. IBM acceptance records indicate a satisfactory quality level.

A MIL specification for the 6414 will probably be available some time this year. Life-test data is being gathered on the allowable plate current change per tube during life to permit a quantitative definition of this parameter.

It is interesting to note that General Electric "Operation Snow White," the closely controlled environment originally instituted for the type 6414/0528, has been expanded by G.E. to include all of its computer tubes.

b. Raytheon Manufacturing Company

Considerable progress has been made at Raytheon, second source of the 6414, on the problems reported in previous QPR's. The grid manufacturing problem has been brought under control during this period. They have been meeting delivery schedules with tubes that are within specifications but with characteristics not as well centered as they should be for high quality tubes. By 1 June 1957 approximately 20,000 tubes had been delivered. Procurement from this source is not a problem at this time because ample quantities for SAGE requirements are coming in from the prime source. The simultaneous centering of amplification factor and of the two plate current limits continues to be a major problem. However, the present Raytheon emphasis on the effects of contact potential should gradually result in control of these parameters. A Raytheon consultant confirmed Group 65's proposal that cleaner grids are necessary to solve their processing problem. Tests have indicated that electronic bombardment of the grids will also

assist in the control of these characteristics and an exhaust machine adapted for grid bombardment will be used in production. Tests are being conducted on the same lot of cathode material that General Electric is successfully using on their 6414 in an effort to further control contact potential.

2. Dual-Control Gate Pentode (Type 6888/SR-1782A)

a. Sylvania Electric Products Inc.

Production of the 6888 was resumed by Sylvania at their Brookville plant after a shutdown dictated by the accumulation of a large inventory. Tight factory controls have been instituted and yield is at a satisfactorily high level.

The only important specification item unresolved at the beginning of the current period was pulse-plate current. The importance of this characteristic was recognized at the outset of the development program. The complexity of pulsed measurements in production and lack of knowledge of the exact factors in the tube art upon which this current depends precluded tight control at that time. The 1,000-tube test reported in the last Quarterly Progress Report indicated the tube design changes necessary to increase the pulse-place current and maintain the same level at +25 volts drive as at the +10 volts drive. The minimum levels and statistical control of the lower average limits of pulse-plate current will be set after manufacturing data is gathered. The specified end-of-life value for this pulse current will also be increased when life data shows this to be possible.

b. Bendix Aviation Corporation, Red Bank Division

Bendix has been able to produce in excess of the demand at Kingston. Their product quality has been satisfactory at incoming inspection and after 5,000-hour life test.

Bendix has changed its #1 grid material from gold-plated D nickel to gold-plated molybdenum to achieve stronger and more uniform #1 grids.

Bendix was informed of the grid design change instituted by Sylvania to improve the pulse-plate current specification and of our intention to include a better pulse-current limit in the specification. They constructed tubes with the smaller suppressor grid and confirmed Sylvania's result. Processes unique to each vendor resulted in a dimensional difference between the Bendix and Sylvania design. IBM sent Bendix the Sylvania specifications for the grid designs. The letter was an official notification and not necessarily a specification for Bendix to follow.

Bendix has been pursuing certain tests on the 6888 which involve lining up the three grids. At present the #1 grid and #2 grid are aligned, but the #3 grid is wound in the opposite direction. Bendix feels that the use of three aligned grids would be advantageous from a manufacturing point of view. They are preparing 25 samples of this design which will be available for examination and test the next quarter.

3. High-Power Twin-Triode (Type 5998/2399, DT-438/DT-587)

a. Tung-Sol Electric Company

Tung-Sol broke through in this quarter and started to produce acceptable quality 5998's at a good yield in adequate quantities. A reserve stock is available at Kingston and production, for the first time, exceeds demand with the result that Tung-Sol is building an inventory large enough

to consider shutting down this line. However, continuity of production is one of the prerequisites to the production of high quality electron tubes, and the possibility of a shutdown is undesirable.

Tung-Sol is working, as their own project, on an improved high-power "triode" design (DT-587) which is actually a tetrode connected as a triode and is designed to duplicate 5998 characteristics with wider electrode spacings. Number 1 grid has more turns per inch and greater grid-to-cathode spacing than in the 5998. Number 2 grid acts as a virtual plate and provides the electric field for tube operation but carries only a small portion of the total current. The plate, which is of conventional design, is internally connected to #2 grid and receives almost the total current flow. By modifying the #1 grid in the manner above, better control of plate current can be achieved due to the reduction in "island" effect which is predominant in any closed spaced tube. Larger grid to "effective" plate spacing is a further result of this modification. Preliminary tests on a scaled down version of this design were reported to be encouraging. Tung-Sol is now tooling to make a tube of rated current-carrying capacity.

On 20 May Tung-Sol, Inc. purchased the Chatham Electronics Industries business. The recently expanded plant remains the property of the former owners, the Gera Corporation, which is reported to be a textile firm holding company. Tung-Sol has a long-term lease on the property and announced that they intend to make no changes in operations or personnel at Chatham. The implications of this acquisition could be of importance to us because Chatham was second source.

b. Chatham Electronics Industries

Chatham, second source of the 5998, corrected their cathode peeling problem. Several lots, totaling 2,000 tubes, of satisfactory quality have been received and have had satisfactory life. The major shrinkage item for Chatham tubes is intermittent shorts to which this type is susceptible due to close electrode spacings.

During the next quarter it is expected that Chatham will start to ship 5998's which are constructed to pass special SAGE test requirements including the M.I.T. intermittent-shorts test and the –65 volts cutoff test. These tubes will be known as type 2399, the last four numbers of the IBM part number, and will be the next step in improving the 5998.

c. Bendix Study Contract

The close interelectrode spacings (approximately 0.006" – 0.007") of the 5998 high-power twin-triode have always aggravated the intermittent-shorts problem. The advisability of investigating all reasonable possibilities of improving the reliability of the tube type by increasing the interelectrode spacings resulted in an IBM study contract being awarded to Bendix Aviation Corporation, Red Bank Division. They were to study ways and means to increase interelectrode spacings without changing the 5998 electrical characteristics and to make some handmade samples for test.

Their final report recommended a twin-triode of four sections (cathodes) with extra cathode area to compensate for the loss in transconductance which resulted from the increased spacing. While the electrical characteristics were close, the Ip-Eg curve between 0 bias and –65 volts bias indicated that further work would be required to make the design electrically compatible with the 5998. Bendix considered that these characteristics could be achieved in manufacture by the proper adjustment and design.

Because of the work being done at Tung-Sol and the relatively small demand for the tube type, further IBM sponsorship of the work was discontinued although Bendix intends to pursue it to a limited extent with their own funds and report the results.

d. 5998 Heater-Cathode Leakage Studies

An investigation of the high heater-cathode leakage rate for the 5998 was undertaken in cooperation with the M.I.T. Chemical Engineering Department and Tung-Sol. Previous observations had shown that leakage was more prevalent with the cathode at a positive potential with respect to the heater. It was hypothesized that migration of tungsten through the heater insulation caused the leakage. Four sets of twenty tubes each were constructed and placed on life test to determine whether a glazed coating would eliminate or slow down the migration by reducing the cracks and porosity of the granular coating.

All of the experimental tubes were Tung-Sol's 5998 minus the grid and plate assemblies, and were processed at Tung-Sol to the 5998 schedule. One set had standard Tung-Sol heater-cathode assemblies with unsprayed cathode sleeves. Two sets contained M.I.T. experimental glazed heater coatings with unsprayed cathode sleeves. The fourth set contained M.I.T. experimental glazed heater coatings with sprayed cathode sleeves. All tubes were put on life test at E_h = 7.5 v and 300 v d-c between cathode and heater – a severe operating condition intended to accelerate disclosure of any weaknesses.

After one month on test, half of the tubes had failed because of excessive leakage. The failures included all of the tubes with Tung-Sol standard heater coatings and approximately one-third of the tubes with glazed heater coatings. Although the glazed coating slowed up development of leakage, more work must be done on the process before recommending it for incorporation into a production line.

4. XD-1 Receiver Tube Removals

Critically important tubes installed in XD-1 were early production or prototype models of the following types: 6414 (Z2177), 5965, 5998, 2420 (6888). The major symptom of failure in receiver tubes removed from XD-1 this quarter was low output or no output which is a normal end-of-life characteristic. Intermittents, shorts, and microphonics accounted for only a small percentage of the failures. The low incidence of intermittents is of interest for computer reliability.

D. RESEARCH

1. Electroluminescent Storage

Seventeen tubes were designed and constructed for the electroluminescent studies of Group 24. Three tubes were used by Group 24 on their own vacuum systems to study the behavior of CdS layers under electron bombardment. The remaining tubes were made with a two-fold objective of finding and evaluating surfaces:

(a) with photoconductive properties capable of tolerating high-temperature vacuum processing,

(b) which will not contaminate the oxide cathode of a vacuum tube.

During this quarter surfaces prepared by Sylvania, G.E., Group 24, and Group 65 were studied.

GROUP 65

A series of chemical and vacuum experiments was performed to develop techniques of applying conductive films on the electroluminescent layer. Further chemical experiments were designed to seal the electroluminescent layer before the top conductive film is applied. One of the problems in this area is that pinholes in the electroluminescent layer permit electrical leakage between the top and bottom conductive films.

A new program was initiated to make glass-embedded electroluminescent layers. Initial experiments were carried out to sinter glass powders to conductive-coated glasses. Then, in a second series, electroluminescent powders were added to the glass powder and sintered as an electroluminescent layer. The problem in this case was to find a glass powder that would carry the phosphor undisturbed while the powder was sintered to the conductive glass plate. Test equipment is being acquired and set up in the Barta Building to evaluate the progress of these promising electroluminescent experiments.

2. Phosphor Studies

Two cathode-ray tubes with 2-inch faces and P12 screens were constructed for the phosphor-study program of Group 63.

3. Ferroelectric Switching

Chemical and vacuum experiments were performed to produce on barium titanate a pattern of conductive electrodes to which leads would be attached for the ferroelectric switching studies of Group 63. Sample barium titanate crystals have been obtained from Harshaw Chemical, Bell Laboratories, Professor Pulvari of Catholic University, and the Research Laboratory of Electronics of M.I.T. Ten cathode-ray tubes were designed and constructed to aid these studies.

P. Youtz J. S. Palermo
T. F. Clough S. Twicken

SAGE DC AND CC SITES

GROUP 66

Morriss, B. E., *Leader*
McVicar, K. E., *Associate*

Bragar, P.
Brock, L.
Callahan, T. R.
Croke, J. J.
Hedison, H.
Holden, W.
Ippolito, W.
Linehan, L. H.
Manning, F. F.
Mayer, R. P.
Roberts, A. J.
Sergio, L. S.
Shorey, R. R.
Smiley, E. L.
Thompson, S. L.

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VI. SAGE DC AND CC SITES
GROUP 66

A. SUMMARY

Group 66 made considerable progress during the quarter toward the installation and check-out of the air defense computer program at the first three SAGE sites. On 20 May 1957, three months ahead of schedule, the air surveillance part (Package B, which is approximately 50 per cent of the entire DCA program) for the New York Sector at the McGuire Direction Center was turned over to Western Electric for initial systems testing. Installation of the program at the Stewart Direction Center of the Boston Sector started on schedule on 1 April 1957. A large number of the adaptation and modification parameters for both the New York and Boston Air Defense Sectors was established and transmitted to the respective direction centers.

Formation of the Syracuse Combat Center team and the Syracuse and Fort Lee Direction Center teams began in the quarter. Total staff members in the group increased, by about 60 people, to about 300 by the end of the quarter; the great majority of the group is still RAND people.

B. E. Morriss
K. E. McVicar

B. LEXINGTON

Group 66, consisting of about 90 staff members, continued its management and support of field activities and carried on program modification and adaptation, test planning, information planning (formerly called documentation), and liaison with the Program Development Group (Group 67) and the RAND Technical Services Group.

Approximately 75 per cent of the modifications necessary to convert the DCA program, as written for the XD-1 computer by Group 67, to AN/FSQ-7 computer operation was accomplished during this quarter. Modification reports which describe the necessary conversions were issued. The adaptation parameters were established and transmitted to the McGuire and Stewart Direction Centers for adapting the air surveillance programs specifically to the New York and Boston Sectors, respectively. Adaptation parameters for the first version of the McGuire weapons direction portion of the program were also established and transmitted to the McGuire Direction Center.

The test support section, in conjunction with the program modification and adaptation section and the Kingston site, developed a card and tape identification system (described in memorandum 66D-HQ319-1) which significantly increased the utility, ease of handling, and maintenance of changes to the tapes and card decks processed at all sites. Initial design of a "program control" procedure was described in 66D-HQ380. As part of this activity, a central control and program discrepancy report was issued and Kingston began using this control.

P. Bragar
V. Ippolito
L. Linehan
R. P. Mayer
L. Sergio

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C. McGUIRE

The air surveillance part of the DCA program was adapted to the New York Sector, completely checked out and turned over to Western Electric for initial system testing of the McGuire Direction Center on 20 May, three months earlier than had been anticipated. The operation of the air surveillance part of the direction center system was successfully demonstrated and no major difficulties were experienced in program operation. The only deficiency was an error in the masking routine for simulated data which caused uncalled-for rejection of simulated returns; for the purposes of this preliminary system testing, the masking routine was eliminated. A revised version of the air surveillance package is scheduled for release on 1 July 1957 and will include corrections to the known errors and changes that result from ESS system testing.

The test plans for the weapons direction part of the DCA program were nearly complete by the end of the quarter and installation of adapted weapons direction programs was begun.

T. R. Callahan
H. Hedison
W. E. Holden
A. J. Roberts
R. R. Shorey
A. R. Shortell
S. L. Thompson

D. KINGSTON

The Kingston operation involved approximately 100 people during this quarter. Principal activities included:

(1) Training and staging for field test teams

(2) Operating computer and card room equipment as necessary for Group 66 assembly tests and DCA "package processing," Group 67 parameter tests for the DCA program, and Group 60 assembly and parameter test for the CCA program.

Other site teams began to take form during the quarter. The Syracuse Combat Center Test Facility Section (which included Group 60 and Group 66 staff) initiated its activity, working on compilation and parameter tests for the Combat Center Program Development Group (Group 60). The test facility teams for the Syracuse and Fort Lee direction centers also began to form and to assume corresponding duties at Kingston in preparation for program installation at those sites, to be started on or before 1 September 1957. About 60 new staff members entered the training activity at Kingston.

Package B (air surveillance) and Package D (weapons direction) were processed for the McGuire and Stewart Direction Centers during this quarter. This processing included card-deck check and reproduction, geographic adaptation and machine modification by compilation and/or recompilation, instruction-deck listing, and some null-cycle testing.

Standard procedures for computer and card room operations, reporting functions, document indexing, etc., were devised and recommended for use at all sites. Job responsibilities and definitions were better specified. An additional 3600 square feet of office and classroom space was provided to accommodate the increased number of people planned for the activity by mid-summer. Computer time used during the quarter totaled about 1500 hours, approximately the

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same amount as was available during the preceding quarter. Over 960,000 IBM cards were processed, as against 600,000 during the previous quarter.

L. Brock
J. Croke
F. F. Manning

E. STEWART

The Stewart program-installation team completed its preparatory work at Kingston and moved to the Stewart Direction Center on 15 March. Installation of the utility system programs was begun on 1 April. All of the necessary material and equipment for program installation and checkout (cards, tapes, plugboards, etc.) were obtained through the Kingston operations. Reliability of both computers was encouragingly high during the quarter, and the utility system was completely installed in about two weeks.

Test plans were completed for the air surveillance part of the DCA program that had been adapted to the Boston Air Defense Sector and assembly testing was started.

The entire program-installation team was on site at Stewart by the end of the quarter. All members of the team are RAND people.

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COMPUTER PROGRAM PRODUCTION

GROUP 67

Zraket, C. A., *Leader*

Arden, Marguerite
Bagley, P. R.
Bailey, D. L.
Bensley, E. H.
Briscoe, H. W.
Budd, Eleanor
Burrows, J. H.
Byrne, W. P.
Chandler, A. R.
Clapp, Elizabeth
Collins, L. B.
Coyne, J. D.
Earl, D.
Ferguson, Mary
Frachtman, H. E.
Gochman, H.
Hager, L. S.
Hills, Merithew
Jones, K. L.
Kirshner, H. J.
Latimer, D. P.
Lundberg, E. D.
Marko, J. T.
Marnie, G.
Miller, J. F.
Newhall, H., Jr.
Ornstein, S.
Patton, R. L.
Port, S. C.
Rising, H. K.
Stone, J. H.
Thomas, L. M.
Vance, P. R.
Wilson, L. D.

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VII. COMPUTER PROGRAM PRODUCTION
GROUP 67

A. SUMMARY

Packages B and C of the DCA program were delivered to Groups 64 and 66 for testing and evaluation on 4 March. Assembly testing of Package D was carried on throughout the quarter and it was ready for delivery on schedule on 1 June. Package D contains all air surveillance and weapons direction functions except automatic crosstelling and forwardtelling which are to be delivered with Package E on 24 September. Operational improvements in the program have resulted in a significant gain in useful operating time. A study was begun of the DCA program to measure the capacity of the present system and to anticipate computer system requirements for 1959 SAGE, when operational requirements will be increased. A preliminary finding has shown that the present program frame time is compatible with the 100-track, 50-intercept initial SAGE system.

An automatic system for documenting programs has been written which uses the computer to store, keep up to date, and read out any part of the DCA program; the new method is much faster and more accurate than the manual system which it replaces.

It is planned that by 15 July 1957 all RAND people in Group 67 will have been released to the RAND Program Development Group, taking with them the responsibility for any further changes in the SAGE DCA program. Group 67 will develop an experimental program in ESS to test new air defense functions and techniques before they are included in SAGE. They plan, for example, to investigate a new timing structure for the DCA program which would incorporate a two-subframe, 12-second frame, instead of the three subframe, 15-second frame now in use.

C. A. Zraket

B. DCA PROGRAM PRODUCTION

Packages B and C of the DCA program were delivered to Groups 64 and 66 on schedule on 4 March. Intensive assembly testing of Package D was then begun, and emphasis was placed on modifications to and improvements of the program structure. The following functions were modified, with a saving of 8233 registers of drum storage: raid forming, selecting and telling of tracks, radar inputs, and intercept direction. These modifications carried to completion the program design changes undertaken in the previous quarter.* In addition, a complete redesign of the storage and sequence structure significantly increased available program operating time. Group 67 continued to maintain and operate the DCA program in support of ESS shakedown testing.

1. Assembly Testing of Package D

Having delivered Packages B and C to Groups 64 and 66 on 4 March 1957, Group 67 carried on assembly testing of Package D. The preparation of the program structure had been taking place prior to the delivery of Package D, so that the skeleton of the program was available in

*Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 March 1957) Sec. VII.B.

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mid-March. In the course of preparing Package D for delivery, a number of operational improvements were made. Those which have the most direct effect on ESS testing are described below:

(a) The raid-forming function was revised to eliminate all automatic positional monitoring of tracks in raids, the automatic selection of lead track, and the generation of mean velocity and altitude information for the raid itself; 1575 registers of drum storage were saved.

(b) In a review of the functions of selecting and telling of tracks to manual AAOC's and manual subsectors, the following specifications were modified and standardized: selection of tracks, priority schemes, message formats, and data transmission; 1980 registers of drum storage were saved.

(c) A number of modifications were made to the radar-inputs function; for example, the set-status control (the switch insertion feature which provides for system override) was eliminated; 3803 registers of drum storage were saved.

(d) The intercept-direction function was revised, with a saving of 875 registers of drum storage, as follows:

  (1) Foldback vectoring was deleted, but the sensing and display of foldback conditions was retained.

  (2) Automatic change of tactics for final turn interception was continued from Period 3 to Period 4, and the sensing condition was changed to make the program more sensitive to the alarm condition.

  (3) The number of iterations for obtaining a heading angle for a lead-collision, final-turn interception has been decreased in order to save program operating time.

  (4) The time-to-go calculation for a lead-pursuit interception was improved.

  (5) Test messages for data-link were clarified and standardized.

  (6) Certain attention devices were deleted or modified.

In addition to the above modifications, a complete redesign of the storage and sequence structure was incorporated in Package D.* The redesign included a reallocation of storage for subprograms and data tables in core memory and on the drums, a revision of the sequence in which programs operate, and the sequence in which transfers of data are made between core memory and all input-output equipment.

Package D of the DCA program contains all air defense functions in the initial SAGE system except automatic crosstelling and forwardtelling. Duplex operation was added to the DCA program three months ahead of schedule. The functions of Package D are:

radar inputs
manual initiation
automatic tracking
data simulation
recording
automatic initiation
track monitoring
height-finding
manual inputs
identification
situation and digital displays
weapons assignment
intercept direction
Army Air Defense Command Post
raid forming
subsector command post
manual crosstelling
startover and duplex operation.

*Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 March 1957) Sec. VII.B.2.

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The above functions can be performed simultaneously for 100 tracks of which 50 can be interceptions. The system will process up to 2000 radar returns per frame in the automatic tracking program (i.e., after the program masking process), and will store and display eight scans of this data at one time. Package D requires 86,016 registers of the 102,400 drum registers available in the AN/FSQ-7. When delivered, Package E is expected to require 6,000 additional drum registers, making a total of about 92,000 registers for the initial SAGE DCA program. The capacity of the system in diagrammatic form is shown in Fig. 67-1.

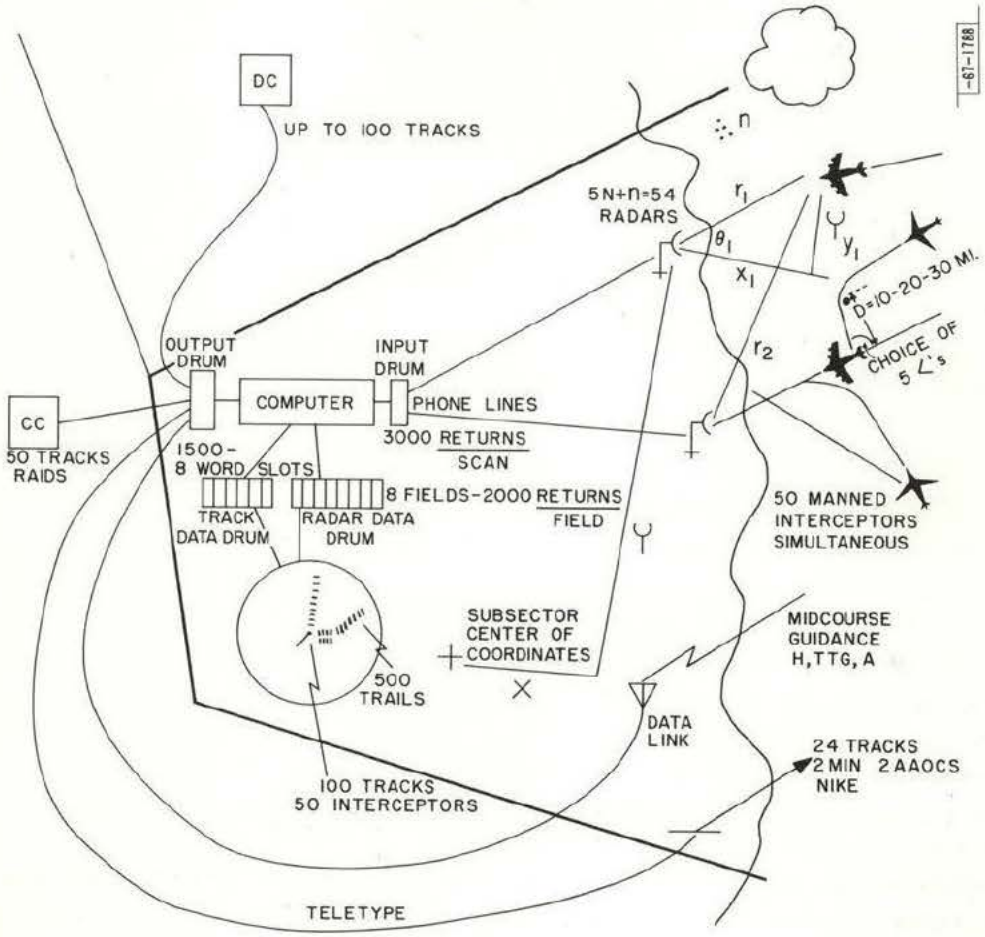

Fig. 67-1. Capability of initial program.

2. Group 67 Contribution to ESS System Tests

Group 67 personnel continued to assist in ESS testing by operating the DCA program during ESS tests. They read the DCA program into the computer, produced and duplicated DCA tapes and, where possible, made corrections to the program during the test. In cooperation with IBM and Group 62 they also attempted to isolate program, equipment, or operator troubles in the system.

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Group 67 receives from Group 64 reports of program problems which describe apparent discrepancies in program operation that are observed during ESS system tests. In some cases, the reports are requests for information; in others, questions of interpretation of specifications. During the period 1 December 1956 through 31 May 1957, a total of 40 reports was received from Group 64. Of these, approximately 60 per cent involved programming errors which were later corrected. The remainder of the reports were inquiries for information, descriptions of transient conditions attributable to equipment malfunction or operator error, and questions of specification interpretation.

H. J. Kirshner

C. DCA PROGRAM SUPPORT ACTIVITIES

A complete redesign of the storage and sequence structure of the DCA program has resulted in a significant reduction of transfer time, with an equivalent gain in usable program operating time. The redesign included (1) reallocation of storage for subprograms and data tables in core and drum memories; (2) a revision of the sequence in which programs operate; and (3) a revision of the sequence in which transfers of data are made between core memory and all input-output equipment.

Changes in the DCA program must be periodically posted in order that programmers who are writing, analyzing, and modifying the program may be kept up to date. A newly incorporated computer processing system automatically documents detailed DCA program and table design data, handling it more rapidly and more accurately than the manual systems formerly used.

1. Revision of Storage and Sequence in the DCA Program

The DCA program is divided into about 70 component subprograms that are designed to operate sequentially, the cycle of operation being repeated over and over again with a continuing inflow and outflow of data. Each subprogram is a dependent unit, communicating with other component subprograms or systems outside the computer. In processing the data received, the AN/FSQ-7 operates within the time limitation of the 15.7-second program frame; i.e., operational functions are performed by the AN/FSQ-7 at intervals of, or multiples or submultiples of 15.7 seconds. Within the frame, time is divided between program operating time and control time. A gain in useful program operating time and an equivalent increase in the capacity of the system as a whole has been achieved by reducing the amount of control time used to transfer data. The program revisions described below are the result of efforts to reduce total control time by finding the sequence of program events which has the least number of transfers of data and by overlapping control time with program operating time whenever possible.

(a) Tables, used by one or more program units, were stored permanently in core memory.

(b) Some short tables were stored in direct sequence with other tables most often used with them so that they can be transferred as a group.

(c) Program units with a common need for one table were grouped together so that one transfer of the table serves them all.

(d) Certain unavoidable transfers were scheduled to occur while the program was operating; for example, a table used by a previous program unit but not required by the operating unit can be returned from core to drum.

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(e) Certain transfers, not associated with any subprogram, have been made to occur while lengthy program units are operating so that the transfer time is overlapped with useful program operating time.

The revisions to the DCA program described above are estimated to have reduced by one-half the time consumed by control functions in the program. Under realistic maximum load conditions, the total transfer time in the 15.7-second frame is estimated to be 11.6 seconds of which 4.2 seconds are overlapped with the program operating time. Available program operating time is thus 8.3 seconds. Upon installation of the 65,000-register core memory in the AN/FSQ-7, the time consumed by transfers of data from drum storage to core memory will be eliminated since the larger memory will have the capacity to store all of the tables; the entire frame time will be usable for operating time, thereby allowing significant increases in program capacities and improved program design.

Late in the quarter a study was begun of the program operating time, especially as it will be affected by system requirements and capacity in 1959 SAGE. Measurements of the present system capacity, being taken to support this study, have justified a preliminary finding that the program frame is compatible with the 100-track, 50-intercept, initial SAGE system.

2. DCA Automatic Documentation Program

The component parts of the DCA program are subject to analysis and modification by programmers as improvements are introduced to the system. In order to have easy and reliable access to any part of the program, the programmers have available a listing in which program elements are identified by coded tags. Considerable time and effort has been expended to maintain the usefulness of the listing of periodic revisions as changes in the DCA program take place. A newly incorporated computer processing system automatically documents detailed DCA program data, handling it more rapidly and more accurately than the manual systems formerly used. The entire automatic documentation program is stored permanently in the computer. A control program, operating continuously, reads control cards punched with a statement defining the requested output, and brings in and operates the necessary program. For example, an operator wishing a list of tables need only read in the proper control card ("produce table listing"): the computer then reads out the desired information on a tape recording which is subsequently converted into a printed listing of tables. Some of the more important advantages of this system as opposed to the manual or card processing system are as follows:

(a) The automatic documentation program frees technical design manpower from the routine job of coordinating changes throughout several publications. A job which formerly consumed at least 35 hours per week is now accomplished in less than 1 hour.

(b) The documentation program enables the program designer to make faster and more accurate measurements of the DCA program and insures the timeliness of the information published.

(c) The chance of operator error is greatly decreased since manual handling is necessary only at the input to the process.

(d) It is easier to add to and modify the computer documentation program than it was to introduce changes to the manual or card machine process.

H. K. Rising

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D. COMPUTER OPERATIONS OFFICE AND UTILITY SYSTEM

1. Computation Support by the IBM 704

The newly delivered IBM 704 computer will be used to relieve the load on XD-1 by taking over the output processing of test results after the assembly testing of DCA programs. A detailed specification for a suitable program has been prepared.

2. Input and Output Instrumentation

The input instrumentation system consists of a set of programs which provide a means of simulating program intercommunication tables, keyboard inputs, and radar data during DCA program operation. The output instrumentation system provides a means of recording specified blocks of registers at specific points in the operation of the DCA system for test purposes and of later (non-real-time) translating this data into mnemonic alphanumeric form. Most of the facilities contained in these two systems have been operating for several months. Documentation of the entire output instrumentation system was completed during the quarter. The complete bibliography is presented in 6M-4979, "Bibliography for Output Instrumentation Programs."

3. Manual of Operation for the Lincoln Utility System

A manual containing introductory and operational information on the Lincoln Utility System, 6M-5165, was drafted during this period. The manual has been written primarily as a reference to aid the user of the utility system. Little detail is presented concerning the internal operation of the programs which comprise the system; rather, summary data, which assumes that the reader has a basic understanding of the system programs, has been prepared for his use.

J. H. Burrows

E. FUTURE PLANS OF RAND PERSONNEL AND GROUP 67

1. The Reassignment of RAND Personnel to RPDG

By 15 July 1957 all RAND personnel in Group 67 will have been released to the RAND Program Development Group (RPDG). On that date Group 67 will relinquish responsibility for the SAGE DCA program. RPDG will carry out all further changes, corrections, and improvements made to the SAGE program and will test and deliver Package E.

The chief responsibility of Group 67 during the next year will be to develop an experimental program in ESS to test new air defense functions and techniques before they are processed for inclusion in the production SAGE System. Some of the projects now being planned include:

(a) The study of a new timing structure for the DCA program which will incorporate a two-subframe, 12-second frame instead of the three-subframe, 15-second frame now in the program. Among other things, the effect of this change on the quality of the automatic tracking process will be studied.

(b) The system timing-response studies and measurements started during this quarterly period (see Section C) will be continued.

(c) A review will be made of the stereographic projection system and slant/range correction now in the radar-inputs program to determine whether a more accurate and simpler form of the mathematics can be formulated.

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(d) An evaluation of the automatic tracking program will be started to determine whether improvements in positional and velocity accuracy in track life continuity can be obtained by means of changes to the logic of the present program. The dual-tracking techniques suggested by Group 22 will also be tested in ESS with techniques to be developed for the initiation and tracking of high-speed tracks.

(e) An operational plan for an emergency capability in the SAGE System will be formulated in cooperation with the Air Defense Command.

(f) In cooperation with representatives of Group 61, IBM, and Boeing Airplane Co., a non-real-time simulation system of programs will be written for the IBM 704 computer for a study of SAGE tracking and BOMARC guidance requirements.

(g) The design of an automatic crosstelling test facility for ESS will be started.

(h) Crosstelling requirements for the 1959 SAGE System will be formulated and an operational specification written.

(i) The design and implementation of the ESS program for the control and makeup of time-division data-link messages will be started. This program will be used in time-division data-link system tests to be conducted in the spring of 1958 in ESS.

(j) Computer program studies and tests will be started for the functions of weapons assignment, intercept direction, NIKE control and Mark X SIF tracking in the 1959 SAGE System.

C. A. Zraket

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SYSTEM OFFICE

GROUP 68

Brown, D. R., *Leader*

Boyd, H. W.
Ginsburg, S. B.
Giordano, J.
May, J. P.
Ogden, W.
Parkins, T. R.
Rupp, A.

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VIII. SYSTEM OFFICE
GROUP 68

A. SUMMARY

The System Office was established in March to gather and coordinate all available information regarding changes that are proposed to the computer programs, equipment, or operating procedures of SAGE direction or combat centers. In May, the Design Control Office of Group 62 became a part of the System Office, since program or operational changes to the Experimental SAGE Sector will be handled in a manner similar to the SAGE changes. The equipment changes in ESS which can be accommodated by local arrangements will continue to be the responsibility of Group 62.

Many organizations involved in the design, installation, or operation of the SAGE System (e.g., Lincoln, RAND, IBM, ADC) will recognize areas where a change to the system may be advantageous from the standpoint of air defense capability. Proposed changes will be submitted to the System Office, which will request from IBM, RAND, and others, the production schedule, number of computer instructions, number of computer hours, and man-power information on which to base an evaluation of the change in terms of increased air-defense capability.

B. 1959 REVISED PROGRAM

A committee composed of members of the System Office began meeting four days per week in March to discuss the requirements for the September 1959 revision of the SAGE computer program. Mr. Pat Beeby of IBM's product engineering group visited Lincoln early in May to discuss IBM's thinking regarding the equipment changes that will be an important part of the 1959 revision. Of initial concern will be the additional output sections for the computer that will be needed for the integration of the time-division data link and the BOMARC frequency-division data link.

C. DATA LINK

By the end of the quarter, the System Office had gathered the necessary data and was writing a recommendation covering the additional time-division and BOMARC output sections. Upon completion of the recommendation, it will follow a standard procedure of submittal, first to the persons directly involved with the change (those who proposed it, those who will carry it out, and those who will use it). These persons will certify as to the accuracy of the description of the change, the reasonableness of the statement of gain which may be expected from making the change, and the accuracy of the cost and schedule information included in the recommendation. The certifying organizations will include various groups within Lincoln, RAND, IBM, the 4620th ADW, and the Lincoln Project Office. The recommendation will then be submitted to the heads of Divisions 2 and 6 for approval and, if approved by these representatives of Lincoln management, will be released by TIR.

D. R. Brown

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ADMINISTRATION AND SERVICES

GROUP 60

Proctor, J. D., *Leader*

Arnow, J. A.
Attridge, W. S., Jr.
Biagiotti, R. J.
Essler, G.
Falcione, A. M.
Ferguson, M. M.
Grover, C. S.
Hazel, F. P.
Heidler, G. R.
Hill, A. P.
Hodgdon, H. W.
Jacobs, J. F.
Johnson, F. B.
Kates, W. A.
Levenson, Judith
Miller, R.
Morley, H. B.
Smith, A. R.

IX. ADMINISTRATION AND SERVICES
GROUP 60

A. SUMMARY

The main activity of Group 60 is of a supporting nature. The General Engineering Section, furnishing design, fabrication, and assembly services to the Division reports as noteworthy the following apparatus which is being designed for Group 63 in support of their experimentation and development in computer memories: a mold to produce plastic forms which will facilitate the assembly of miniature core memories; equipment for carrying out experiments with evaporated metallic films.

J.C. Proctor

B. GENERAL ENGINEERING

1. A Vacuum Assembly Form for 50-30 Memory Cores

In the continuing development of miniature memory planes for experimental computers, the smallness of the ferrite cores that constitute the memory has made the handling of them a problem of its own. Each core measures 0.050" outside diameter and 0.030" inside diameter – considerably smaller than the cores used in FSQ-7 and other Lincoln Laboratory computers. In order to assemble a 64 × 64 plane, four wires (each approximately 0.005" diameter) must be threaded through each of 4096 cores, brought out to terminals on a frame, and soldered.

To hold the cores in place during the threading operation, a vacuum chuck, similar to that used for larger memory cores* was called for. Three means of producing a chuck were investigated: (1) by pressure molding cavities in thermosetting plastic (a technique previously used for 80-50 cores); (2) by etching rectangular openings in a brass sheet; and (3) by punching rectangular openings in a thin micarta sheet. The aim in all three schemes was to produce holes, or cavities, which would hold each core in an upright position, but not so snugly as to make withdrawal difficult; these conditions having been met in a test sample of relatively few holes, they had to be maintained with virtually no variation in a 4096-hole production molding. The design work has led to the fabrication of a mold for pressure-molding cavities in thermosetting plastic.

As shown in Fig. 60-1 the core rests on the edges of the cavity, is held upright by the sides of the opening; the lower opening is the vacuum port. To machine the mold, it was necessary to mill all the projections running in one direction in a metal block, and all the projections running in the other direction in separate strip blanks which were subsequently soldered into slots prepared in the block.

2. Support For Thin Films Research

Several pieces of apparatus have been designed for use by Group 63 in its experiments with thin metallic films.† Fig. 60-2 shows some of the essential equipment used in this work, including the following parts designed by General Engineering, Group 60:

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*Quarterly Progress Report, Division 6, Lincoln Laboratory, M.I.T. (15 March 1955) Sec. VIII.

†See Sec. III. B. 2. of this report.

GROUP 60

A A substrate holder (for securing the glass plate and mask) which can be warmed by resistance coils or electron bombardment during the experiment and cooled by circulating water afterwards,

B A telescoping shield which confines the vapor, making unnecessary the frequent cleaning of the inside of the bell jar,

C A pair of shutters to afford precise control of deposition time,

D A 4-post stand which permits vertical adjustment of the substrate holder, shield, and shutter assembly,

E An access ring which has the double advantage of raising the jar for increased working space and providing a number of service entrances for manipulators, wires, and tubes.

Other equipment (not pictured) designed by Group 60 to facilitate the experiments includes:

Manipulators, operated through bellows-type seals, which enable the operator to open and close shutters, rotate the sample, and balance a single turn coil,

Helmholtz coils, arranged around the outside of the bell jar, which control the ambient magnetic field.

A. R. Smith G. R. Heidler
G. Essler L. B. Prentice

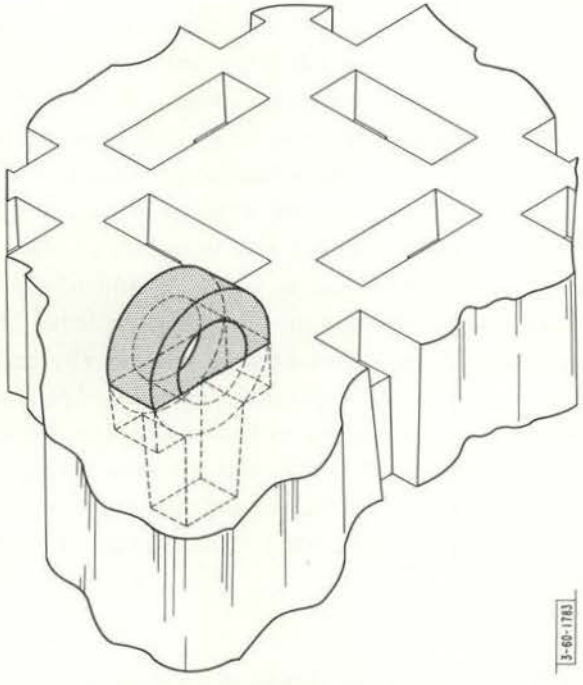

Fig. 60-1. Portion of vacuum assembly form, showing one 50-30 ferrite core in place (enlarged 40×).

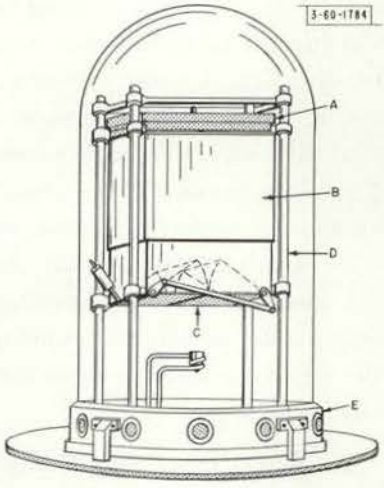

Fig. 60-2. Vacuum deposition system, showing essential apparatus designed by Group 60, General Engineering.

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